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PROCEEDINGS

of the

Indiana Academy of Science

Founded December 29, 1885

VOLUME 46

PAUL WEATHERWAX, Editor

Field Meeting held at
Taylor University, Upland
May 15-16, 1936

Fifty-second Annual Meeting
Central Normal College, Danville
November 5-7, 1936

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TABLE OF CONTENTS

	Page
Officers and committees for 1936	5
Minutes of the Council Meeting	7
Minutes of the Spring Meeting	8
Program of the Winter Meeting	9
Minutes of the Executive Committee	11
Minutes of the General Session	17
Necrology	18
Presidential Address—**Ray C. Friesner:** Indiana as a critical botanical area	28
Program of the section on Archeology	46
E. Y. Guernsey: Certain southern Indiana sources of lithic artifact material	47
Eli Lilly: The use of copper by the American aborigines	53
C. F. Voegelin: Anthropological limits of language	57
Program of the Section on Bacteriology	65
H. M. Powell and **W. A. Jamieson:** Maintenance of antiseptic action by "Merthiolate" as a preservative	66
Program of the Section on Botany	71
Winona H. Welch: Studies in Indiana bryophytes	72
J. E. Potzger: Notes on Indiana grasses, 1936	79
William D. Gray: Observations on the methods of stipe-formation in Stemonitis and Comatricha	81
R. B. Zumstein: Fungus growth as affected by varying concentrations of salts	86
J. E. Potzger and **Florence Geisler:** Some physical features associated with pliability of wood	88
J. E. Potzger and **Ray C. Friesner:** Soil acidity and hemlock reproduction in relic colonies in Indiana	93
Program of the Section on Chemistry	100
John F. Deupree and Robert E. Lyons: Selenium dioxide as an oxidant	101
T. H. Chao and **R. E. Lyons:** Selenocyanation of aniline	105
T. H. Chao and **R. E. Lyons:** The production of hydrogen selenide by heating paraffine with selenium in the presence of a catalyst	107
E. W. Kanning and **E. H. Lewis:** Conductometric titration of iron, aluminum, and magnesium	109
J. W. Kroeger, F. J. Sowa, and **J. A. Nieuwland:** Catalytic esterification with dihydroxyfluoboric acid	115
R. J. Hartman and **D. H. Jung:** A fractionation column employing adsorbents	118
W. W. Binkley and **Ed. F. Degering:** The preparation and properties of 2,3,4,6-tetraethyl-alpha-ethyl-*D*-glucoside	124
Ed. F. Degering: Lecture demonstrations in organic chemistry	128
Ned Guthrie: The preparation and properties of some ethoxy-compounds	130

Page

F. M. Whitacre and **H. T. Briscoe:** Esterification in the presence of anhydrous salts 133

Program of the Section on Geology and Geography 142

S. S. Visher: Indiana regional contrasts in soil erosion and their chief causes 143

Alfred H. Meyer: Auto-planetabling, an economical and expeditious method of geographic mapping 160

Stuart L. Schoff: Oölites in the Green River formation of central Utah, and the problem of oölite growth 167

Program of the Section on Mathematics 171

C. G. Schilling: On a class of ruled surfaces generated by an algebraic correspondence 172

Alson H. Bailey: A group of projective transformations associated with a conic section 176

Program of the Section on Physics and Astronomy 179

D. B. Green: The addition of two frequencies in audio apparatus 180

Gaylord S. Kurtz: Discharge of electricity from the leaves of forest trees .. 184

A. L. Foley: Wave velocity 187

Chas. T. Knipp: A cold cathode rectifier 190

Program of the Section on Psychology 192

Frank R. Elliott: Visual, auditory, and visual-auditory material 193

Edmund S. Conklin: Family adjustment influences in the neurotocism score 199

Program of the Section on Zoology 202

B. Elwood Montgomery: Records of Indiana dragonflies, IX. 1936 203

J. P. Scott: Inherited behavior in Drosophila 211

Raymond M. Cable and **William Hugh Headlee:** The incidence of animal parasites of the brown rat (*Rattus norvegicus*) in Tippecanoe County, Indiana 217

W. P. Allyn: Studies on poisonous snakes of Indiana 220

A. E. Reynolds: Additional observations on the salamanders of Putnam County and vicinity 225

J. J. Davis: Insects of Indiana for 1936 230

Chapman Grant: Orthogenetic variation 240

Chapman Grant: The "Midventral Keel" in Testudinata 246

W. E. Martin: A new second intermediate host of the trematode (*Gorgodera ampliclava*) 253

Program of the Junior Academy of Science 254

Meetings of related groups 256

Past Officers 257

List of members 259

Index 279

OFFICERS AND COMMITTEES FOR 1936

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Psychology, E. S. CONKLIN, Indiana University.
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STANDING COMMITTEES

(Appointed by the president; first named on each committee is chairman)

Archeological Survey: E. Y. Guernsey, Eli Lilly, W. N. Logan, Glenn A. Black, C. A. Malott, R. A. Esarey.

Auditing: E. S. Martin, William Johnson.

Biological Survey: B. E. Montgomery, Winona Welch, C. M. Palmer, S. R. Esten, M. W. Lyon, Jr.

Library: J. E. Potzger, Will Scott, W. E. Edington, Glenn A. Black.

Membership: S. W. Witmer, F. E. Beghtel, M. S. Markle, L. J. Rettger, Winona Welch, G. Don Klopp, O. B. Christy, Wm. Thornbury, E. R. Martin, Theodore Just, A. R. Bechtel, C. F. Deppe, R. E. Girton, Edward Kintner, F. R. Elliott, W. J. Tinkle, Henry Nester.

Program: Leslie I. Steinbach, J. C. Nelson, J. E. Williams, W. J. Tinkle, G. H. Evans.

Publication of Proceedings: J. J. Davis, C. A. Behrens, E. R. Smith, F. B. Wade, M. E. Hufford, Paul Weatherwax.

Relation of Academy to State: F. N. Wallace, J. S. Wright, Stanley Coulter, Will Scott.

Research: A. L. Foley, J. S. Wright, E. G. Mahin, W. E. Edington, R. B. Abbott.

Representative on A.A.A.S.: H. E. Enders.

Nominations: (To be announced later.)

Junior Academy: H. E. Enders, F. B. Wade, O. B. Christy, W. P. Allyn.

MINUTES OF COUNCIL MEETING

At the call of President Friesner, the Council of the Academy met in the Purdue Union, Lafayette, March 15, 1936, at 1:45 P. M. Those present were: Abbott, Behrens, Bruner, Cogshall, Davis, Enders, Foley, Friesner, Johnston, Kintner, Malott, Mellon, Montgomery, Morgan, Potzger, Steinbach, Test, Wade, and Weatherwax.

Dr. Weatherwax, as editor, reported that the cost of the Proceedings for 1935 would be $1300 besides the editor's expenses. He moved that the Council authorize the expenditure of not more than $600 to supplement the $1000 provided by the State. The motion carried.

The Secretary read a letter from General Secretary Caldwell, of the A.A.A.S. relative to research grants, and this question was discussed. It was suggested by Dr. Enders that the research grant of approximately $125 be supplemented by funds taken from the endowment fund sufficient to make a total of $200. Action on this was deferred until November.

A motion that the awarding of research grants this year be left to the research committee was amended to include the President and Secretary of the Academy on the committee and then carried.

President Friesner read an invitation from the Botanical Society of Edinburg to send a delegate to the centenary of the Society to be held July 1, 1936. It was taken by consent that the President appoint as delegate anyone who would probably attend the meeting.

A communication from the World Calendar Association regarding calendar reform was referred to a committee consisting of Dr. Cogshall and Dr. Edington to report in November.

In a discussion of the meeting of the A.A.A.S. in Indianapolis in 1937, President Friesner reported that within less than a mile of the Circle there were 16 rooms available for meetings of groups of 125 or more and 40 rooms holding from 60 to 100. The possibility of securing churches and other auditoriums was also mentioned. The appointment of the following committee to assist Dr. Ward in making arrangements for the meeting was announced: Frank Wallace, Stanley Coulter, A. W. Butler, John S. Wright, Glenn Black, Tom Hendricks, H. T. Davis, Peter Reilly, Christopher Coleman, Eli Lilly, James Stewart, Hilton Brown, Richard Lieber, William Book, Hugh Landon, Leo Rappaport, J. W. Putnam, Frank Wade, Evans Woollen, Paul Stetson, W. P. Morgan, Virgil Simmons, Mayor Kern, Merle Sidener, Arthur Baxter, Charles Lynn, and H. E. Enders. The date of the meeting was announced as December 27, 1937, to January 2, 1938.

Dr. Weatherwax spoke of some of the problems of the editor. He suggested that the publication committee consider the question of papers published from year to year as parts of series, with the idea of curtailing series which had outlived their usefulness. He explained his method of sending to authors printed suggestions for the preparation of manuscript and of returning manuscripts to authors for revision. His action in requiring that an author's dues to the Academy be paid before his papers were eligible for publication was approved, as was the

plan of paying one-fourth of the cost of the first 100 reprints ordered by each author. Other editorial problems were referred to the committee on publication.

Dr. Potzger, reporting for the Library Committee, said that an effort was being made to complete some broken sets. His suggestion that an effort be made to begin binding the unbound material was referred to the November meeting for discussion. He reported that the committee was endeavoring to arrange for exchanges with all the academies in the country.

Dr. Steinbach reported that arrangements were being made for the spring meeting at Taylor University, May 15 and 16, and the fall meeting at Central Normal College, November 5-7.

Mr. Johnston's suggestion, that copies of the Proceedings be sent to the libraries of the larger newspapers of the State, was referred to the Library Committee.

L. A. Test, *Secretary.*

MINUTES OF THE SPRING MEETING

TAYLOR UNIVERSITY, UPLAND

May 15 and 16, 1936

The first session of the spring meeting was called to order in the College Chapel, by President Friesner, on May 15, at 7 p. m. In the absence of President Stuart, Dr. Tinkle gave a short address of welcome.

Dr. J. E. Potzger spoke briefly of the plants about Dollar and Galatia Lakes, and Mr. Harold A. Zimmerman spoke of the birds of the vicinity. Dr. Marcus W. Lyon, Jr., gave a short address, illustrated by lantern slides, on "Elephants, Past and Present."

At a short business session the Treasurer of the Academy was designated as the official to whom the research grant from the American Association was to be paid. Dean Stanley Coulter was announced as the chairman of the committee in charge of arrangements for the A.A.A.S. meeting to be held at Indianapolis in 1937. Announcement of the trips for Saturday were made.

Saturday was spent in trips as scheduled on the program, beginning with a visit to Walker Museum. Visits to the places where skeletons of extinct elephants have been found were the principal feature of the field trips.

At the noon luncheon on Saturday, ten new members were elected; a report of the Resolutions Committee, expressing the appreciation of the Academy for the fine hospitality shown by Taylor University, was adopted; and an appropriation was made for compensation to the farmers on whose land the field trips had been made.

L. A. Test, *Secretary.*

PROGRAM OF THE WINTER MEETING

Central Normal College, Danville

November 5-7, 1936

THURSDAY, NOVEMBER 5

7:30 p. m. Meeting of Executive Committee, Administration Building.

FRIDAY, NOVEMBER 6

9:30 a. m. General Session, Administration Building.

Address of Welcome—President Carl H. Griffey, Central Normal College.

Business Session.

Necrology—Read by Dean Emeritus Stanley Coulter, Purdue University.

J. B. Burris	J. P. Kerr
Hal H. Coffel	J. A. Nieuwland
S. D. Conner	George Spitzer
A. F. Foerste	Mrs. Etta Wilson
W. A. Guthrie	D. D. Van Osdal

Otis S. Roberts

"Regional contrasts in soil erosion in Indiana."
S. S. Visher, Indiana University.

"Our versatile atmosphere." F. J. Allen, Purdue University

"Observations on the Proceedings of the Indiana Academy of Science." (Read by title)
Robert Hessler, Indianapolis.

11:00 a. m. Sectional Meetings. For programs of the sections see: archeology, p. 46; bacteriology, p. 65; botany, p. 78; chemistry, p. 100; geology and geography, p. 142; mathematics, p. 171; physics, p. 179; psychology, p. 192; zoology, p. 202.

12:00 m. Luncheon.

1:30 p. m. Sectional meetings continued.

4:30 p. m. Tea for members of the Academy and their guests through the courtesy of the Faculty of the College.

6:30 a. m. Annual Dinner.

Final business session.

President's Address: "Indiana as a critical botanical area."
Ray C. Friesner, Butler University.

Moving pictures: "Indiana snakes."
W. P. Allyn, Indiana State Teachers College.

SATURDAY, NOVEMBER 7

9:00 a. m. Junior Academy of Science, Business meeting and exhibits. See page 254.

9:00 a. m. Systematic botanists' meeting. See page 256.

9:00 a. m. Entomologists' meeting. See page 256.

1:00 p. m. Program of Junior Academy. See page 254.

3:00 p. m. Football game—Central Normal College vs. Oakland City College. Members of the Academy and Junior Academy were invited to the game as guests of the College.

MINUTES OF THE EXECUTIVE COMMITTEE

The fifty-second annual meeting of the Executive Committee was held in the Recreation Room of the Administration Building of Central Normal College, November 5, 1936. The meeting was called to order by President Friesner at 7:30 P. M. with about 35 members of the Committee and Academy present. The minutes of the Council meeting of March 15 were read and approved. Reports of officers and committees followed.

Academy Foundation. John S. Wright presented the following report:

The Trustees of the Academy Foundation recommend that the income of the Foundation Fund be administered by a committee composed of the following Fellows:

Five-year term—Chairman, A. L. Foley, Physics; four-year term—Howard E. Enders, Zoology; three-year term—Charles C. Deam, Botany; two-year term—John S. Wright, Business; one-year term—E. G. Mahin, Chemistry.

The trustees wish to explain that the only reason for not recommending a continuation of all the members of the old Research Committee is that, under the requirements of the original grant, no two members of the Committee shall be from the same branch of science.

The financial statement of the Trustees is as follows:

Receipts

Balance from previous year	$ 439.00
Interest on investments	229.97
From Treasurer of Academy (Acct. A.A.A.S.)	90.50
From a friend of the Academy	500.00
Total	$1,250.47

Expenditures

Withdrawal for purchase of $1000 par value Consolidated Federal Farm Loan Bond of 1944-46 (plus interest, $2.89)	$1,085.39
Balance in bank, November 1, 1936	165.08

Present Assets at Par Value

United States Treasury Bonds	$4,200.00
Consolidated Federal Farm Loan Bonds	1,500.00
Muncie Masonic Temple Association Preferred Stock	200.00
Standard Oil Company of Indiana Common Stock	150.00
Balance in Bank	165.08
	$6,215.08

Archeological Survey. Mr. E. Y. Guernsey, Chairman of the Committee, made the following report:

While field operations during 1936 have not been as successful as was anticipated, two very important conclusions may be established as a result of the field work of Mr. Black and your chairman.

In Allen County, as studied by Mr. Black, it has been determined that this section, which is rich in Indian history and tradition, has been influenced very slightly by prehistoric peoples. A careful survey of the county reveals the fact that the known village sites generally represent late, historic occupation and that the region is disappointingly barren of earlier landmarks and remains.

In Harrison, Crawford, Lawrence, and Orange Counties your chairman has continued his preliminary survey of aboriginal quarry sites; it may be concluded that

southern Indiana comprised one of the most prolific sources east of the Mississippi of materials used for the fabrication of projectile implements. Within a region roughly 500 square miles in area, several hundred quarry sites exist, and it has been ascertained that the distribution of this material has been considerably more extensive than was hitherto believed.

During the year Mr. Black's excellent report on the excavation of the Nowlin Mound, Dearborn County, was published by the Indiana Historical Society. Our own report covering the survey and excavation of various aboriginal sites in the vicinity of the Ohio Falls is nearing completion. This has been delayed because of the numerous complexities involved and the abundant material recovered from these sites. It is believed that these several allied sites represent the most extensive occupational center so far studied in Indiana.

Auditing Committee. The report of this committee was postponed until the end of the fiscal year. At that time the Treasurer's report was audited and found correct.

Biological Survey. The committee reported progress during the year, as follows:

1. Lyon's "Mammals of Indiana" appeared in print as Vol. 17, No. 1, of the American Midland Naturalist in January, 1936. This monograph includes a thorough systematic treatment and notes on life history for each of the species of Pleistocene and recent mammals for which there are trustworthy Indiana records. It is well illustrated, containing 125 figures (photographs, drawings, and diagrams of the various animals, or of such anatomical structures as are of special taxonomic significance, of habitats, etc.) and 85 maps showing distribution of Indiana records.

2. Deam's flora of Indiana is near completion.

3. Miss Welch has continued her work on the mosses of Indiana, and this report is now in an advanced stage of preparation.

4. Deay and Gould's "Gerridae of Indiana" was published in Vol. 17, No. 4, of the American Midland Naturalist. This is the first part of a proposed monographic revision of the Hemiptera of the State.

5. The same authors have a paper on the Cicadidae of Indiana in the program of the present meeting. This, likewise, is a part of a proposed similar treatment of the Homoptera, a group which, except for the scales, has been almost entirely neglected in the State.

6. Montgomery's Odonata of Indiana has received very little attention during the year. The manuscript is, however, practically complete, and it is expected that the entire report will be finished within three or four months.

7. The status of the bibliography of the Indiana biota is unchanged from last year. As pointed out at that time, little further progress can be expected until there is some prospect of publication. Members of the committee and collaborators cannot develop much enthusiasm in the preparation of a manuscript which must wait indefinitely for publication and which, in the meantime, requires constant revision to include new titles as they appear.

The Committee suggests that the bibliography in its present form may be made more or less available by the preparation of a list of the monographs, catalogues, lists, general works and summaries, together with notations concerning the status and location of the bibliographies of the different systematic groups. Such a list has been prepared for the insects and related groups. A copy of this list is included in this report for the files of the Academy. It will be read by the chairman of this Committee before the Entomologists' Meeting Saturday morning.

The Committee recommends, as in previous years, the desirability of building a fireproof museum for the storage of scientific specimens which have been collected in Indiana, either at one of the state universities or in Indianapolis. Many of our sister states, notably Illinois, Ohio, and Michigan, have excellent facilities for the care and study of scientific specimens. Much valuable material has been sent out of the state because of the lack of a suitable place for its preservation here. This loss of specimens will continue until an adequate museum is established.

Bonding Committee. Dr. Bruner, Chairman of the Committee, reported that the bond of $2000 for the Treasurer and $2500 for each Trustee of the Academy Foundation had been renewed with the Hartford Accident and Indemnity Company.

Editor. Dr. Weatherwax, as Editor, reported as follows:

Volume 45 of the Proceedings was ready for distribution to members about August 10. It consisted of 345 pages, as compared with 284 pages in the preceding volume; but the increase in scientific and historical material was approximately 80 pages. The size of the edition was the same as of Volume 44; of the 1500 copies printed, 1000 were bound in cloth.

The net cost of manufacturing the volume was $1,396.67. The Editor's expenses and the cost of reprints charged to the Academy brought the total cost to $1,531.48. After the deduction of $1000 appropriated by the state, the total cost to the Academy was $531.48. The net cost per printed page was $4.05. This is somewhat higher than last year, the difference being due to the greater amount of illustration and the terms of the new state contract.

Authors' orders for reprints were handled as last year, one-fourth of the cost of the first 100 being charged to the Academy. The cost of this item to the Academy was $56.49. The printer's scale of prices for reprints, although essentially lower than that quoted at the time at which the orders were taken, was not fully equitable to all authors. A better arrangement is promised for another year.

In editing the material for this volume it was necessary to reject a few papers because they did not comply with the editorial policy adopted in 1934. Many of the papers published were returned to their authors for various kinds of revision or condensation, and a few were withdrawn when the need of such revision was pointed out. General directions for the preparation of manuscript and illustrations have been sent to the authors of papers listed in the program of this meeting.

Library. The Committee on Library, with Dr. Potzger as Chairman, reported as follows:

Your committee, working in conjunction with Miss Coats of the State Library, had two meetings during the past year to discuss the needs of our library. The services of Mr. Leland Smith of the Butler Library were again engaged to carry out some necessary clerical work. Exchanges sent and received were checked, and addresses of all institutions and societies who did not respond with exchange publications were removed from our addressograph list. Work is now in progress toward arranging for exchanges with all other state academies.

On the shelves of our library were numerous incomplete sets of periodicals, many represented by but one copy. Upon the suggestion of Miss Coats, the members of your committee, augmented by professors Mallott and Switzer of Indiana University and Mr. Wade of Shortridge High School, checked this incomplete aggregation of periodicals for possible valuable single copies to be retained for the library. Lists of the rejected material were sent to various second-hand booksellers for an offer. No offer was made.

In order to correct the mailing list, mimeographed reply cards were placed in all copies of the Proceedings sent out, and all recipients who did not reply were addressed in a special letter by Miss Coats.

The Committee recognizes as one of the greatest needs of the library the binding of periodicals, and it recommends that an appropriation for this purpose be made annually.

Dr. Edington has placed in care of the library all slides, films, pictures, and other historical material which he has collected.

The Committee asks for instructions as to the disposal of the incomplete sets and single numbers of periodicals and on the suggestion that copies of the Proceedings be sent to newspapers of the State.

After a discussion it was voted that the Committee be empowered to use $100 from the funds of the Academy for binding periodicals.

Membership. A brief statement was made by the Chairman, Dr. Witmer, and the complete report was deferred until the business meeting on Friday evening.

Press Secretary. Mr. T. R. Johnston, Press Secretary, reported as follows:

The Press Secretary has endeavored to give publicity to the meetings of the Academy by providing suitable publicity in advance of the meetings, newspaper coverage while the meetings are in progress, and proper reports at their close.

Some difficulty has been experienced because of his inability to attend the meetings and because only a few of the speakers have supplied extracts of their papers in advance. Those who have sent them in have helped to give adequate reports of the meetings to the press and to radio stations, but too few of the features on the program have received publicity.

It was proposed some months ago that the Proceedings, when printed, be sent to editors of certain newspapers with a letter explaining why they were sent. This was done this year and was partly successful in keeping the work of the Academy before the public. In the opinion of the Press Secretary this policy should be continued with some variation from year to year.

Program Committee. Dean Leslie I. Steinbach presented the printed program as the report of his committee and supplemented this with a brief explanation of the plan of the meeting.

Publication of Proceedings. Chairman, J. J. Davis, reported as follows:

The Committee on Publication of Proceedings has functioned, as in the past, in an advisory capacity to the Editor. As a guide for the future, your committee makes the following recommendations:

1. Inasmuch as authors of memorials often wish a few copies to send to friends, but seldom more than a half dozen, it is recommended that the Academy pay for 100 reprints of the combined memorials and that these be parceled out to the authors.

2. Until a few years ago cuts used in the Proceedings were returned to authors on payment of postage. It is recommended that cuts having a historical value, such as portraits, buildings, etc., be properly stored in the State Library for possible future use; that other cuts be returned to the authors who wish them and will pay the cost of transportation; and that if cuts are not requested within one year after use in the Proceedings, they may be sold or destroyed.

3. Keys, notes on distribution, and other annotated lists are permissible in papers on fauna and flora; also full descriptions of new species and definitely improved descriptions of other species. However, it is recommended that the Editor may refuse to publish descriptions merely copied or similar to those already published.

Relation of Academy to State. In the absence of Chairman Wallace an informal report of the work of the committee was given. Following a general discussion of the work of this committee, a motion was passed that the Academy ask the State Legislature for an appropriation of $3000 per year for the publication of the Proceedings, for the binding of material received in exchange by the State Library, and for the publication of additional scientific material.

Research. The report presented by the Chairman, A. L. Foley, was as follows:

The activities of the Research Committee of the Indiana Academy of Science for the year 1935-36 may be summarized as follows:

The Committee has made a plea for funds for needy students, and for the establishment of scholarships and fellowships,—particularly for grants to encourage and to aid research. The appeal has centered around the memorial idea, that a fellowship or research fund given in the name of some loved one would be, and would continue to be, a living, enduring memorial which, unlike a block of marble, would be of service, not only to the recipient, but to the cause of education and science down through the years. After marshalling the arguments for such gifts, and assigning them amongst

the members of the Committee, each member wrote a communication,—an appeal, and these were published week after week in the INDIANAPOLIS STAR, in regular sequence. It is hoped that the seeds thus sown many in due time bear fruit.

A second job for the Committee was the drafting of a set of regulations governing all future applications for aid from the Research Fund of the Academy. Copies of these regulations, as now drawn, are in the hands of each member of the Executive Committee (Published at the end of this report.) Suggestions for the improvement of the proposed regulations are invited.

Lastly, understanding that certain allowances made by the American Association for the Advancement of Science would lapse if not used promptly, and having received several applications for grants from the fund, the Committee recommended grants to the following:

Professor C. M. Palmer, Butler University, Indianapolis, Indiana, Professor R. E. Martin, Hanover College, Hanover, Indiana, Mr. Scott McCoy, 3444 N. Illinois Street, Indianapolis, Indiana.

The regulations under which these grants were made are as follows:

Applicants for grants from the Research Fund of the Indiana Academy of Science, or from that portion of the Research Fund of the American Association for the Advancement of Science that has been allotted by the Association to the Indiana Academy, should include in their application a full statement of their academic training and career, of the character of their research problem and their proposed methods of attack, and of the use to which they wish to apply the grants requested. Applicants should include written statements from responsible workers in the field in which the applicant wishes to work, certifying as to the importance of the investigation, to the applicant's ability to prosecute it to a definite conclusion, and to the reasonableness of the estimate of the cost.

Applicants are reminded that the research funds of the Academy are quite small and that they should make their requests as definite or as moderate as possible. Other things being equal, the Committee will favor small grants to a larger number of applicants, rather than large grants to a very few.

The recipient of a grant is required to sumbit semi-annually an expense account covering the funds placed at his disposal, together with a statement of the work accomplished. The mid-year report may be brief. The final report should be reasonably complete and should be filed with the Research Committee not fewer than ten days in advance of the regular annual fall meeting of the Academy.

The Indiana Academy of Science shall have first call on the publication of any paper or papers reporting results of investigations for which the Academy has borne any part of the expense.

Applications for grants may be made at any time, but to insure prompt action they should be submitted to the Committee at least ten days before the regular fall meeting of the Academy.

While a grant for a second year (but no longer) may be made, no preference will be shown any applicant because of his previous award. Each applicant for a second grant must file a second application, including an account of the disposition of the first grant, what was accomplished by it, and for what purpose a second grant is requested.

When a grant, or any portion thereof, is used for the purchase of equipment, such apparatus or equipment is to remain the property of the Indiana Academy of Science to be loaned, awarded, or retained, as the Academy may direct.

Treasurer. The complete report was deferred until the end of the fiscal year, December 31. The following report was later made by Treasurer Morgan and approved by the Auditing Committee:

Receipts

Balance on hand January 1, 1936	$956.87
Dues and initiation fees collected	887.00
A.A.A.S. Refund for Research Grants	100.00
Sale Proceedings Vol. No. 45	3.00
Author's Reprints Vol. No. 42	4.10
Author's Reprints Vol. No. 43	19.35
Author's Reprints Vol. No. 44	26.37
Author's Reprints Vol. No. 45	222.38
	$2,219.07

Disbursements

1—Program Committee	$205.34	
2—Expenses of Editor	87.32	
3—Expenses of Secretary	54.16	
4—Expenses of Treasurer	30.50	
5—Mailing Proceedings	89.85	
6—Academy Library	54.75	
7—Stationery	59.90	
8—Indianapolis Engraving Co.	261.20	
9—Fort Wayne Printing Co.	429.35	
10—Junior Academy Bulletins	20.00	
11—Surety Bonds and Safety Deposit Box	20.50	
12—Research Grants	150.00	
13—Checks Returned	3.00	
		$1,465.87
Balance in Bank		753.20
		$2,219.07

Junior Academy. The following report was submitted by Dr. H. E. Enders, Chairman:

Your Committee on the Junior Academy of Science has continued in touch with the 17 member clubs of last year and has endeavored to stimulate them by correspondence and by circulation of the SCIENCE CLUB SERVICE, published by Louis Astell and made available by a grant of $20 from the Academy.

The chairman of your Committee visited 14 schools in March and April and spoke to more than 2000 pupils in clubs or before the schools.

At this time we have six new clubs to recommend for membership, making a total of eleven accessions for the year. The total number of clubs now affiliated is 28, and their aggregate membership equals that of the Academy.

We have reason to believe that the Academy has rendered a valuable service by cooperating with the Illinois Academy of Science and several other academies in the publication of the SCIENCE CLUB SERVICE. We recommend that the Indiana Academy continue its appropriation of $20 per year to assist in this work.

The program of the Junior Academy is scheduled for Saturday morning and afternoon. All members of the Academy are urged to attend these meetings and to view the exhibits of the clubs. Last year 14 clubs were represented, and 140 members and sponsors were present.

The Executive Committee voted to continue the appropriation of $20 for the SCIENCE CLUB SERVICE.

A.A.A.S. Dr. H. E. Enders, the Academy representative in the Council of the American Association for the Advancement of Science, made a brief informal report.

Nominations. Chairman Mahin reported the recommendation of E. Y. Guernsey for fellow in the Academy.

Special Committee. W. A. Cogshall, reporting for the Committee on Calendar Reform, recommended the calendar which divided the year into four equal quarters.

New Business. The following committee was appointed to receive invitations and make recommendations for the place of the next regular fall meeting of the Academy: W. E. Edington, Chairman, S. R. Esten, J. C. Nelson, W. J. Tinkle, and A. R. Bechtel.

A Committee on Resolutions was appointed, consisting of Paul Weatherwax, C. M. Palmer, and Theodore Just.

At the request of Professors Behrens and Tetrault, a separate section of Bacteriology was recognized.

After a discussion of various features of the program, two regulations were passed:

1. In the future no papers are to be accepted to be "read by title", the implication being that the author should be present or should designate someone to present his paper.
2. Before a paper can be placed on the program, an abstract must be sent to the chairman of the section before which the paper is to be presented.

MINUTES OF THE GENERAL SESSION

The meeting was called to order on Friday morning by President Friesner. Dean Steinbach introduced President Griffey, of Central Normal College, who gave an address of welcome. President Friesner responded in behalf of the Academy.

The minutes of the Executive Committee were read and approved. Dr. Enders made a brief report on the Junior Academy, and Dr. Friesner made a few remarks relative to the meeting of the American Association for the Advancement of Science at Indianapolis in 1937. The general program followed.

Following the annual dinner on Friday evening a brief business session was held. Dr. Witmer, Chairman of the Membership Committee, announced 54 applications for membership, including six high school organizations for the Junior Academy. All were elected.

The Committee on Resolutions moved a vote of thanks to Central Normal College, the people of Danville, and a number of individuals, all of whom had been responsible for the success of the meeting. The motion carried.

Dr. Edington reported the recommendation of the Committee on Invitation that the fall meeting of the Academy in 1937 be held at Manchester College. The recommendation was adopted.

Dr. Mahin, of the Nominating Committee, nominated the following for officers for 1937, and all were unanimously elected.

President, WILL E. EDINGTON, DePauw University.
Vice-President, C. A. MALOTT, Indiana University.
Secretary, L. A. TEST, Purdue University.
Treasurer, WILL P. MORGAN, Indiana Central College
Editor, PAUL WEATHERWAX, Indiana University.
Press Secretary, M. W. LYON, JR., South Bend.
Academy Trustee, JOHN S. WRIGHT, Indianapolis.

The following were announced as having been elected divisional chairmen by the various sections: Archeology, Glenn A. Black; Bacteriology, H. M. Powell; Botany, C. L. Porter; Chemistry, Paul D. Wilkinson; Geology and Geography, LeRoy Perkins; Mathematics, C. K. Robbins; Physics and Astronomy, Leslie I. Steinbach; Psychology, P. R. Hightower; and Zoology, W. P. Allyn.

Louis A. Test, *Secretary*.

NECROLOGY

John Breckenridge Burris

Putnam County, Indiana, September 5, 1859.

Indianapolis, Indiana, December 5, 1936.

John B. Burris spent the greater part of his life near Cloverdale, in the county in which he was born. He attended DePauw and Purdue Universities, receiving a degree from the latter in 1888. In 1899 he married Harriet McCoy, a graduate of DePauw University, who, with one daughter, survives him.

His major interest in the university was agriculture, and he followed that as his life work. He did educational work in farmers' institutes and was at one time president of the Indiana Corn Growers' Association. He traveled extensively, including one trip around the world.

As a charter member of the Academy, Mr. Burris was present and spoke at the Fiftieth Anniversary Meeting at Indianapolis in 1934. Although not active in the work of the Academy in later years, he was always keenly interested in scientific developments, particularly those applying to agriculture.—*Will E. Edington.*

Hal Herbert Coffel

Montpelier, Indiana, February 2, 1875.

Pennville, Indiana, August 24, 1936.

In H. H. Coffel we had a rare example of many-sided talent, his interests including banking, law, music, ornithology, forestry, and astronomy.

After receiving his formal education in Valparaiso University, the American Correspondence School of Law, and a music school in Chicago, he became president of a school of music in Indianapolis. In later years he was cashier, and then president, of the Pennville State Bank.

Mr. Coffel's publications include a number of musical works and a series of papers on birds. Articles on the birds and plants of Jay County were in preparation at the time of his death. He also gave illustrated popular lectures on ornithology and astronomy.—*Wm. J. Tinkle.*

Samuel Dicken Conner

Connersville, Indiana, June 17, 1872.

Lafayette, Indiana, April 19, 1936.

In the passing of Samuel D. Conner, science lost a keen student, the farmers of the State a wise counselor, and the Academy a well-known and valuable member.

Graduating from Purdue University in 1894, he spent a number of years with a sugar refinery in the South, and some time as a salesman for a fertilizer company, and returned to Purdue in 1899 as a member of the staff of the State Chemist. During the following years his success is indicated by the following appointments: Assistant Chemist in the

Agricultural Experiment Station, 1905; Associate Chemist, 1908; Instructor and Assistant Professor of Agricultural Chemistry in the School of Agriculture, 1906-1913; Associate in charge of chemical work in Agronomy, 1912; Research chemist in charge of the Research Chemistry Laboratory, 1923. He received the degree Master of Science in 1907.

Professor Conner's research dealt largely with the chemistry of soils. A pioneer in the study of soil acidity, he became a widely recognized authority in this field; his studies of muck and peat pointed the way to a profitable utilization of millions of acres of these defective soils. His discovery, in 1912, of aluminum tonicity and borax injury to corn under certain conditions, and his later work on the fixation by the soil of phosphate and potassium fertilizers and the placement of fertilizers for greatest efficiency, are noteworthy accomplishments.

He was an active member of a number of national and international societies devoted to chemistry and soil science.—*A. T. Wiancko.*

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AUGUST FREDERICK FOERSTE

Dayton, Ohio,
May 7, 1862.

Dayton, Ohio,
April 23, 1936.

Although a life-long resident of Ohio, Dr. August F. Foerste always had a lively interest in Indiana and Indiana geology. Little known to most members of the Academy, he was, nevertheless, one of its most distinguished members and was a frequent attendant at its meetings.

After attending the public schools of Dayton, he attended Denison

University, receiving the A. B. degree in 1887; Harvard University granted him the A. M. in 1888 and the Ph.D. in 1890, and Denison conferred the honorary doctorate of science upon him in 1927. He also studied at the University of Heidelberg and at the College de France in 1890-'92.

His scientific eminence was won in geology and paleontology, and he was by profession a teacher; but, strangely enough, he never, except incidentally, taught these subjects. The greater part of his teaching was in physics in the Steele High School of Dayton, where he taught from 1894 until his retirement in 1932.

Dr. Foerste's first scientific interest was in botany. At the age of fifteen, in company with William B. Werthner, well-known botanist and teacher in the Steele High School, he began to explore the countryside around Dayton for plants. His training in geology began under C. L. Herrick, at Denison, and was continued under the influence of Shaler, Davis, and Wolf, at Harvard, Alpheus Hyatt, of the Boston Society of Natural History, and Rosenbusch, Osann, La Croix, and Fouqué in Europe.

His first paper, on "The power of motion in crinoid stems", was published in 1884. His second publication, a series of papers (1885-'88) on "The Clinton group of Ohio", is significant because it established a life-long connection with the Bulletin of the Denison University Scientific Laboratories, a periodical whose fame was to be enhanced by the publication of many of his later papers; and it marked the beginning of his interest in the Silurian, an interest which reached its climax in a summary of the Silurian correlations of the Central States shortly before his death.

Dr. Foerste became connected with the Geological Survey of Ohio in 1892 and continued in that capacity until 1919, doing extensive field work on the Clinton (now Brassfield) group in Ohio. For three years (1896-'99), while connected with the Indiana Geological Survey under Dr. Blatchley, he made detailed studies of the Silurian and late Ordovician in southeastern Indiana, mapping with extreme accuracy the boundary between the two formations. He was always interested in the problem of the nature and age of the Cincinnati Arch and was one of the first to discuss the detailed relations of the various Silurian and Ordovician formations to this structure. From 1904 to 1912 he was connected with the Kentucky Geological Survey, and in 1911 and 1912 he served on the Canadian Geological Survey. From 1932 he spent all of his time at the United States National Museum as Associate in Paleontology, working on the collection of fossil cephalopods. His studies on the Ordovician and Silurian cephalopods during the last fifteen years of his life will stand for all time as a monument to his genius and one of the really great contributions to American paleontology.

His numerous papers will be found fully listed in the Bulletins on Geologic Literature of North America, published by the United States Geological Survey.—*Condensed from a manuscript submitted by E. R. Cumings.*

WILLIAM A. GUTHRIE

Dupont, Indiana,
May 13, 1851.

Dupont, Indiana,
August 5, 1936.

Through self-training in forestry during many years, William A. Guthrie became an authority on forest management. Living in and near woodlands during his entire life, he used the opportunity to secure first-hand an unusual balance between the theoretical and the practical in forestry.

His chief schooling was in Moores Hill (now Evansville) College. In 1875 he was married to Sarah Lewis, who died in Cairo, Egypt, in 1925. He was a member of many scientific and civic organizations, including the Indiana Academy of Science. Although not an active attendant at the meetings of the Academy, he was always interested in its welfare and advancement.

As a member of the State Legislature Mr. Guthrie initiated valuable legislation. He served for a number of years on the State Conservation Commission during the time when the acquisition of several of the state parks was consummated. His civic benefactions included a gift to the Nature Study Club of Indiana of a beautiful wooded area in Jennings County as a forest preserve in memory of his wife.

The "Guthrie Trail", leading from Madison up the hill, beneath the Hanging Rock, through his home town, and northward toward Indianapolis, was named in honor of his far-reaching services, and on his eighty-fifth birthday one of the entrances to Clifty Falls State Park was dedicated in his honor.—*Samuel E. Perkins III.*

JULIUS ARTHUR NIEUWLAND

Hansbeke, Belgium,
February 14, 1878.

Washington, D. C.,
June 11, 1936.

The accomplishments of genius have been variously ascribed to many different qualities. *Talent* and *industry* are, perhaps, most frequently mentioned; *courage* and *ambition*, too, are often stressed; *ingenuity* and *resourcefulness* seem to be necessary; and *a sense of humor* and *love of fellow beings* have inspired genius through all ages and placed men's names in the "Book of Gold."

The Reverend Julius Arthur Nieuwland, C.S.C., possessed all of these qualities in a high degree, and his bibliography attests his accomplishments. His untimely death occurred in Washington, D. C., where he was visiting the chemical laboratories of his Alma Mater. His final resting-place is in the cemetery of the Congregation of the Holy Cross, at the University of Notre Dame, where he spent all of his teaching days, 1904-1936, in the fields of botany and chemistry. He came to South Bend, Indiana, with his parents at the age of four. There he attended the parochial school of St. Mary's Parish. He received his preparatory training for the priesthood at Notre Dame and graduated there from the University in 1899. In December, 1903, he was ordained a priest of the Congregation of the Holy Cross by the late Cardinal Gibbons. He was granted the Ph.D. degree by the Catholic University of America in June, 1904, and was honored by the University of Notre

Dame with the degree Sc.D. in 1911. His major interest was in botany until 1918. He then became Professor of Organic Chemistry, but he retained the editorship of *The American Midland Naturalist*, which he had founded in 1909.

His taxonomic interests resulted in a fine collection of plants of northern Indiana, southern Michigan, New Jersey, Maryland, and Oregon. This and the splendid collection of the late Dr. Edward Lee Greene, his former teacher and friend, constitute the valuable herbaria at the University of Notre Dame. His remarkable knowledge of languages greatly aided him in his worth-while studies in the history of botany, and his interest in this field inspired him in his efforts to accumulate the great botanical library of the University. In connection with the earlier volumes of the *Midland Naturalist* he also edited the well-known series of rare and classical works of *Natural History*.

As a chemist, Father Nieuwland won fame primarily with his substantial contributions to the development of the chemistry of acetylene. Lewisite, a war gas, and Duprene, the most important synthetic rubber at present, are the best known products of his chemical activities. A large number of patents were granted him, both in the United States and in foreign countries, and both scientific and industrial organizations recognized his researches. Gold medals were awarded him by the International Acetylene Association, the Institute of the City of New York, the New York section of the American Chemical Society, and Villanova College. He was councilor of the American Chemical Society and secretary and chairman of its Organic Division. He was also a member of the board of editors of the Journal of Organic Chemistry.

His university duties involved many responsibilities. He was curator of the university herbarium, served as librarian of the botanical library, and was dean of the College of Science from 1918 to 1922 and director of research in organic chemistry from the early twenties to the time of his death. His interest in the Indiana Academy of Science was strong, and he served as its president in 1934. He combined a rare sense of the practical with his idealism for science and education, as is witnessed by the physical monuments which he left for posterity. His warm personality made him a host of friends, to whom he was an inspiration, and who, in turn, inspired him to greater accomplishments. Fellow members of the Indiana Academy of Science, the American Chemical Society, and other scientific societies, as well as his colleagues of the University of Notre Dame, feel his loss keenly and will long hold dear the memory of the priest-scientist of Indiana.—*H. B. Froning.*

(For Dr. Nieuwland's complete bibliography, see the American Midland Naturalist 17(4) : i-xv. 1936.)

OTIS SIDNEY ROBERTS

Fairbury, Illinois, August 19, 1862.

West Lafayette, Indiana, December 19, 1935.

Otis Sidney Roberts received his early education in the public schools of Oxford, Indiana, and later entered the School of Science of Purdue University, receiving the degree, Bachelor of Science, in 1883. As a student in chemistry he developed a close friendship with his

teacher, Harvey W. Wiley. Following graduation he managed a farm for four years, taught in the local district school, and was superintendent of schools at Boswell (1886-1893), Otterbein (1893-1904), and Earl Park (1904-1907).

He returned to Purdue in September, 1907, and served as Inspector in the State Chemist Department until 1910, when he was appointed Chief Inspector, with the rank of Assistant Professor. He served in this capacity until his death, and also as Acting State Chemist from 1925 to 1926.

Beginning his career as inspector in the State Chemist Department a few months after the passage of the State Feeding Stuffs Control Law, Professor Roberts was a pioneer in this new field of work. His sincere, thorough, painstaking, and untiring efforts in the development of the inspection work are, in a large measure, responsible for the enviable position which Indiana has attained among the states having statutes regulating the sale of fertilizers, feeding stuffs, and seeds.

He served on committees of the American Association of Feed Control Officials and cooperated in studies in methods of sampling which are the foundation of the present official methods of sampling feeding stuffs. He was granted a leave of absence upon request of the officials of the State of Illinois for the purpose of instructing their staff of inspectors. For his excellent services in this work he received high commendation. During the period of the war, when farmers suffered injury to their crops from the presence of borax in fertilizers, he made extensive field inspections with representatives of the manufacturers and was instrumental in arranging adjustments satisfactory to both the farmers and the manufacturers without court action. Professor Roberts measured success, not in terms of accumulation of material wealth, but in service. He was a generous contributor to charitable causes. His chief interest was his work. His success was due largely to the intense enthusiasm, loyalty, sincerity, fairness, and thoroughness with which he performed his duties. He was firm and courageous in his convictions, but those with whom he dealt were always impressed with his honesty and sincerity.—*Henry R. Kraybill.*

GEORGE SPITZER

Galion, Ohio, November 30, 1859.

West Lafayette, Indiana, February 27, 1936.

The death of George Spitzer, Dairy Chemist at the Purdue University Agricultural Experiment Station, removed from membership in the Indiana Academy of Science one whose life typified the truly scholarly and scientific attitude. At the age of eleven he moved with his parents to a farm in Huntington County, Indiana. He was graduated with honors from the Lima, Ohio, High School in 1880, attended Kenyon College two years, and then entered Purdue University. After receiving a degree in pharmacy, he became Associate Professor and later Professor of Pharmacy. In 1907 he was appointed Dairy Chemist in the Experiment Station, and he held this position until his death. He received the degree Bachelor of Science from Purdue University in 1910 and at various times did graduate work in the University of

Chicago. Purdue University conferred the honorary doctorate of science on him in 1929.

Professor Spitzer made many valuable contributions to the science of dairy chemistry. For many years his work was centered in the chemical composition, moisture content, and keeping qualities of butter. He was among the first to give attention to the part played by enzymes and proteolytic organisms in the deterioration of butter.

His interest in the welfare of Purdue University was exemplified by his stimulating contacts with the School of Pharmacy, long after he ceased to be formally connected with it, and by the time which he gave unsparingly to research and graduate study and to the development of the physical plant.

He was a keen observer of plant behavior and a lover of flowers. He did a great deal of work in hybridizing and selecting varieties of flowers, and his extensive peony and iris gardens attracted wide attention.—*Henry R. Kraybill.*

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ETTA S. WILSON

Leelenau County, Michigan, July 16, 1857.

Detroit, Michigan, January 5, 1936.

Etta S. Wilson was born in a forest wilderness near Grand Traverse Bay, in Leelenau County, Michigan. Her father was the son of an Ottawa Indian chief, and her mother was Mary Jane Smith, daughter of a pioneer missionary. Such lineage and environment would most naturally lead to a love of the outdoors and to a keen observation of natural activities.

Mrs. Wilson made the most of an unusual opportunity to obtain first-hand knowledge of the roosting and nesting of the passenger pigeon, which was abundant about her home throughout the impressionistic years of youth. She has reported the activities of her father and his associates as pigeon hunters, and she continued to live in her birthplace long enough to see this race of avians entirely exterminated in the late eighties. (See *The Auk* **51**:157-168. 1934.) She was, however, almost fifty years of age before she made a serious study of general ornithology.

Before this she worked for a number of years as a newspaper reporter and a writer of feature articles and stories for magazines. Her interesting experiences, growing out of her unusual ancestry and her opportunities for observation, caused her to be sought out for lectures. For a number of years she lived in Indianapolis, during which time she lectured for the National Association of Audubon Societies. She attended many meetings of the Indiana Academy of Science, where she made close friends.—*Samuel E. Perkins III.*

DAWSON DWIGHT VANOSDAL

Allensville, Indiana, July 30, 1869.

Rushville, Indiana, March 24, 1936.

Dawson D. VanOsdal was a member of a family which seems to have been characterized by an unusual interest in medicine. He, with his two brothers, followed their father in that profession, and his one sister became the wife of a physician.

After receiving an elementary and high school education in Switzerland County and at Edinburg, Indiana, he attended the Miami Medical College at Cincinnati. Immediately after his graduation, in 1894, he began the practice of medicine at Allensville, later moving to Rushville.

Long interested in archeology as a hobby, he became a member of the Academy soon after the formation of the archeological section. Al-

though in poor health, he attended his first and only Academy meeting at Crawfordsville in 1935.

On October 12, 1897, he married Jennie Gary, of Rush County, who, with two sons, survives him. He was a member of the Masonic Blue Lodge, Royal Arch Masons, Scottish Rite and Mystic Shrine, Odd Fellows, Knights of Pythias, Modern Woodmen, American Medical Association, and Indiana Academy of Science.—*Glenn A. Black.*

ALBERT B. REAGAN

Maxwell, Iowa, January 22, 1871. Salt Lake City, Utah, May 30, 1936.

The death of Dr. Albert B. Reegan took from the ranks of the Academy a man who had spent many active years in a study of the details of the life of the North American Indian.

After receiving his elementary education in Iowa and training for a teacher's license in the Central State Teacher's College of Oklahoma, he taught school for several years in Iowa. He later received bachelor's degrees from Valparaiso and Indiana Universities, the master's degree from the latter, and the doctorate from Leland Stanford Jr. University. In 1899 he became connected with the United States Indian Service, a field of work in which he was engaged for more than thirty years. During the last two years of his life he served as special instructor in Brigham Young University.

Dr. Reegan's many years of active field work resulted in the publication of more than 500 papers, a number of them in the Proceedings of the Indiana Academy of Science. A few of these papers dealt with fossil plants and animals in the recovery of which he had assisted; but the greater part of his work was devoted to the folklore, tribal customs, and details of every-day living of the Indians with whom he associated.

He is survived by his widow, Otilla Adelaide Reese Reagan, and two brothers and two sisters.—*P. W.*

PRESIDENTIAL ADDRESS

Indiana as a Critical Botanical Area

RAY C. FRIESNER, Butler University

The student of field botany recognizes that the plants of the present are the results of conditions of the past. He soon discovers, in comparing present with past vegetation, that Nature is not static, that even in short periods of time new colonies of a particular species may appear in a given locality, thrive for a while and even entirely disappear; that the old familiar collecting grounds take on such different aspects, if he is absent for a few years, that they are hardly recognizable; that the field which yielded crops a few years ago is, when abandoned, first a weed patch, then a briar patch and in succession thicket, mixed hard- and soft-wood forest and ultimately beech-maple or oak-hickory hard-wood forest. As topography and climates, including both temperature and rainfall, change over longer or even shorter periods of time, so does the vegetation change, even more markedly,—so that truly there is a struggle going on in Nature, a struggle which means life and death, survival and extinction; and there is evolution of vegetations just as there is evolution of structures within individuals and races.

In these struggles of the past, Indiana has often been a critical battleground, the scene of vegetational front-line trenches, the land of advance and retreat; and even today we shall see that over half of the species of ferns and seed plants occurring in the state are, in Indiana, on the borders of their present-day range and are, therefore, on critical ground. So, I have chosen to speak briefly to-night on "Indiana as a critical botanical area."

Pre-Pleistocene Uniformity

Even though our knowledge of the vegetation of past geologic time, so far as Indiana as a particular area is concerned, is exceedingly scant, what we know of the vegetation of North America in general leads us to the conclusion that Indiana has not always been the critical botanical area which it appears to have been during glacial time and from then to the present.

Available data (Berry, 2, Knowlton, 17) seem to indicate quite conclusively that the entire continent of North America was low and heavily wooded during Cretaceous time and that rainfall was abundant and climate much warmer than now, as well as quite uniform, even far into the Arctic circle. While the ancestors of our modern plants were present at this time, the flora as a whole had quite a different aspect from that of today. That the Cretaceous was a period of both great uniformity and great mildness appears certain from the fact that both temperate and subtropical species flourished side by side and occurred as far north as Greenland and Iceland. Magnolia, sassafras, willow, oak, tulip-poplar, walnut, and other temperate species grew side by side with such tropical or subtropical species as fig, palm, camphor, alligator pear, and others. These same mild and uniform conditions apparently continued far into

Tertiary time with maximum warmth being reached in early Oligocene, when temperate forests covered territory as far north as Alaska, Greenland, and Spitzbergen.

The dawn of Miocene time found our part of North America covered with a vast forest comprising many species identical with, and others very closely related to, those of our present day. Hickories (Carya), oaks (Quercus), walnuts (Juglans), sassafras, beech (Fagus), ash (Fraxinus), iron-wood (Carpinus), sycamore (Platanus), sumac (Rhus), gum (Nyssa), cypress (Taxodium), maple (Acer), elm (Ulmus), linden (Tilia), hackberry (Celtis), persimmon (Diospyros), tulip-poplar (Liriodendron), sweet gum (Liquidambar), magnolia (Magnolia), chestnut (Castanea), and many others appear to have been flourishing in what has been designated (Braun, 3) as a great Tertiary undifferentiated forest-climax, remnants of which may still be found today in the Ozarks and southern Appalachians. The continued uniformity of climatic conditions over much of the northern hemisphere is indicated by the fact that this great undifferentiated Tertiary forest was prevalent over most of North America, Europe, and Asia. The cypress (Taxodium) is known from Miocene beds of Washington and Virginia and from the same period as far south in Europe as Italy and as far north as Greenland and Spitzbergen, thus indicating a climate then at least as mild as southwestern Indiana of today, where its modern descendant reaches its present-day northern limits.

With the close of the Miocene the long period of uniform and mild climate gave way to a lowering of the temperature over the entire northern hemisphere, and by the time the Pliocene period was well advanced the elevation of the Rocky Mountains had reached sufficient height to cut off moisture-laden winds from the west, thus forcing the great undifferentiated forest eastward. This, together with the coming of the glaciers, which, in Pleistocene time, forced the temperate undifferentiated forest southward, very greatly reduced the area occupied by the forest, broke up the great uniformity of climate which had persisted from middle Mesozoic to middle Cenozoic time, and leads us to the time when Indiana presented a climatic and vegetational individuality and began to become a truly critical botanical area.

Pleistocene Battle-Ground

The coming of the glaciers was probably slow enough to permit most of the plant species to migrate southward in advance of them. In North America the pathway for this southward migration was little obstructed because the great mountain systems, then as now, lay in a direction essentially parallel to the path of the moving ice sheets, thus leaving the great valley between as an open highway for migration southward. The limits of maximum southward extension for the last two of these ice invasions occurred in Indiana. The distance beyond the ice sheet to which the temperature was lowered beyond the limits for plant growth obviously varied with the requirements of particular plant species, and in the case of many of them Indiana became the temporary limit of northern distribution. Retreats of the ice were followed by movements of plants northward, only to be forced south again by

subsequent advance of the ice. These alternate southward and northward movements of ice and plants probably occurred many times in eastern North America. Indiana was a critical area for this plant-climate struggle because the edges of maximum extension of each of the last two ice sheets (Illinoian and Wisconsin) are to be found within her borders.[1]

Post-Pleistocene Activity

The final northward retreat of the glaciers was followed by a northward migration of plants. Most of the present day flora must be looked upon as relatively recent in its occupation of the state because only the Knobs area in the south central part is entirely unglaciated; it is hardly likely that any considerable portion of this unglaciated area was suitable as a plant habitat for any of the fern or seed-plant species which now occupy it. It is probable that no point in the area was more than 50 miles from the maximum extension of the Illinoian ice-edge.

We cannot say certainly just how close to the receding ice sheet the plants followed in their return migrations northward, but if we are to judge by the behavior now shown by plants in Alaska where glaciers are today receding, the plants must have kept close pace with the withdrawing ice. It is probable that this northward 'trek' of vegetation showed a zonation not unlike that today shown by vegetation from farthest arctic regions southward; i.e., nearest the ice edge was tundra, and farther away in succession were boreal shrubs, boreal forest, northern coniferous forest, and northern hardwood deciduous forest. The latitudinal width of these zones of migration is hardly to be thought of as comparing with the latitudes shown by their present-day distribution.

The fossil records obtained from study of peat from the bogs of Indiana and adjacent territory (Sears, 28; Houdek, 16; Lindsey, 19; Artist, 1; Fuller, 12, and studies now under way in our laboratory) all bear positive evidence that the great Miocene forest, concentrated into the infinitely smaller area of the southern Appalachians by the rising cordilleras of the west and the advancing ice sheets from the north, now expanded to take on some of its former extensiveness. But the expansion was mostly in the form of differentiated associations, each segregate coming to occupy that area and climate best suited to it. The order of its extension into our territory was fir (Abies) first, followed by spruce (Picea), then pine (Pinus), and finally broad-leaved hardwoods of the forests of today.

This northward movement has continued until we find fir and spruce dominating the northern coniferous forest of southern Canada and northern New England, Michigan, Wisconsin, and Minnesota today, while the broad-leaved hardwoods have become segregated (Braun, 3) into smaller segregates, each becoming dominant and climax types adjusted to particular climatic conditions in areas farther south. The climatic uniformity of pre-pleistocene time thus became segregated into climatic zones and belts and areas whose borders (limits) have been involved in

[1]As a result of the action of this Academy and the energy of its committee on Geological Survey, the locations of these ice edges are marked by appropriate markers where they cross main highways in southern Indiana.

many changes. This has resulted in transforming vegetational uniformity into vegetational differentiation. Four or five of these segregates from preglacial uniformity are today battling for existence and competing with each other for space in Indiana, viz., beech-maple (Fagus-Acer), oak-hickory (Quercus-Carya), white pine-hemlock (Pinus-Tsuga), and oak-beech (Quercus-Fagus), fir and spruce having entirely disappeared and white pine-hemlock almost so. The fact that fir and spruce and pine once flourished in our area is shown by the records of fossil pollen from every bog so far studied in Indiana. These studies all show that from an early abundance of fir and spruce these species declined in favor of pine and broad-leaved species, finally disappearing in the order named. For these species Indiana was a critical botanical area. The fate of white pine has been a little different; reaching its greatest abundance when both fir and spruce were well on their decline and broad-leaved trees were already in dominance, it held its own for a few centuries and then declined much as did fir and spruce except that in reduced percentages it has persisted until the past few centuries and is still to be found in a few places in Indiana. For the pine, also, indiana was and, to some extent today is, a critical area. Whether pine showed forest dominance between the fir-spruce and broad-leaved dominance periods generally in Indiana remains to be determined after more bogs have been studied. Houdek (16) found a pine-dominance in Center Lake in Steuben County, but this dominance was not found by him in the Mineral Springs bog, nor by Lindsey (19) in the Merrillville bog, in Porter and Lake Counties respectively. Artist (1) has shown that farther north (in the Volo bog in Lake County, Illinois) spruce remained an element of the forest for many centuries longer; and still farther north in Minnesota the spruce-fir forest is thought to be at present invading the deciduous forest (Fuller, 12). It is therefore probable that the battle between conifer and deciduous forest, fought thousands of years ago and won in Indiana by the deciduous forest, is still being waged not far north of the former Indiana battle ground. A lowering of the general temperature only a few degrees might bring this conifer-deciduous battle-front back to Indiana soil.

Boreal and Glacial Disjuncts

Evidence of northward migrations of plants following withdrawal of the glaciers is not limited to trees whose story is told by the pollen from peat bogs but is also written on the present-day landscape in the form of disjunct colonies of northern and boreal species now in isolated and scattered sites far south of their main distribution. Time and space will here permit us to consider but a few of the most striking of these.

The lady's Slipper, *Cypripedium reginae* Ait., (Parker, 23, Welch, 34), characteristic of wet, mossy areas of our northern woods, is found in the northern two tiers of counties, but is to be found also in three stations approximately 100 miles farther south in Montgomery, Fountain, and Henry Counties. The False Lily-of-the-Valley, *Maianthemum canadense* Desf., (Parker, 23, Welch, 34), has very similar range with a disjunct station in Putnam County. The Shin-leaf, *Pyrola americana* Sweet and *P. elliptica* Nutt. (Parker, 23), characteristic of northern

coniferous woods, is found in a few scattered localities in the northern two tiers of counties and again in disjunct colonies nearly 150 miles farther south in Monroe County. The Rough-leaved Dogwood, *Cornus rugosa* Lam., characteristic of rocky mountainous woods of the north, is limited to the northern tier of counties except for one station on a steep bluff, known as "Mill-cut Backbone", in the Pine Hills Region of Motgomery County. The Yew, *Taxus canadensis* Marsh., abundant in the coniferous woods of the northeast, occurs in Indiana in four stations, all of them steep rocky bluffs, viz., Turkey Run State Park, Pine Hills, and the Shades in Montgomery County, and along Walnut Creek in Putnam County.

The Bush Honeysuckle, *Diervilla lonicera* Mill., abundant in dry and rocky wooded slopes of the northeastern part of North America, occurs in sandy areas in the northwestern corner of the state and in Steuben County, and has two disjunct stations, one comprising but a few individuals on Bear Creek in Fountain County and the other with more numerous individuals on Turkey Backbone in the Pine Hills Region in Montgomery County.

Another species which gives us an interesting glimpse into the past is *Habenaria clavellata* (Mx.) Spreng., growing in peat moss in a bog about ten miles southeast of Bloomington. The nearest neighboring station for this little plant characteristic of northern woods is in Lake and Porter Counties. This species must have survived adverse conditions of its habitat for thousands of years, only holding its own without advance because the bog in which it occurs is not large and has been shown by Potzger (25) to be at present in a stage of advance rather than the retreat which is characteristic of most Indiana bogs. It may be that this bog has had its ups and downs through the milleniums that have passed since the northern plants migrated back over this territory, never being able to develop far but still holding on and supporting today a flora which includes a number of typically northern species such as *Alnus rugosa* (DuRoi) Spreng., *Dryopteris cristata* (L.) A. Gray, *Osmunda cinnamonea* L., *Osmunda regalis spectabilis* (Willd.) Gray, *Sphagnum*, and *Ilex verticillata* (L.) A. Gray. The club-moss, *Lycopodium complanatum flabelliforme* Fernald, shows a similar disjunct distribution though a very different type of habitat. This species, very characteristic of the northern coniferous forest, occurs in Lake, Laporte, and St. Joseph of the northern tier of counties and has been reported by Welch (33) and Welch and Price (34) for Monroe, Martin, and Putnam Counties, over 100 miles from its northern Indiana stations.

The Wintergreen, *Gaultheria procumbens* L., typical of northern forests and Appalachian highlands, occurs in the northern two tiers of counties, and then again in disjunct stations in the Pine Hills area of Montgomery County and in Monroe, Crawford, and Clark Counties. These outlying stations are each approximately 60 miles from the nearest adjacent station. The Mayflower, *Epigaea repens* L., shows a similar distribution except that disjunct areas were known only in Monroe and Brown Counties.

Every one of the disjunct stations for these relict species represents a critical botanical area in Indiana, where each of the species has

been able to survive since early post glacial times, while in territory immediately surrounding each station the species in question has lost out in the competition with others while its kin have gone on farther north. *Betula populifolia* Marsh. exhibits a peculiar distribution in Indiana. As shown by Deam, it is found in the western half of the northern tier of counties in Indiana (viz., Lake, Porter, Laporte, and St. Joseph) but is found neither west of us in Illinois, north of us in Michigan, nor east of this area in Indiana or Ohio. Apparently this Indiana distribution represents a glacial disjunct from the present-day distribution farther east and northeast in Ontario and New England.

The hemlock, *Tsuga canadensis*, is an illustration of a relict of a northern segregate of the Tertiary undifferentiated forest. In Tertiary time there was no well-marked distinction between boreal and temperate flora. Such a differentiation came later (Braun, 3), as a result of both prairie formation from the west and glacial formation from the north. As this differentiation came, we find Tsuga occupying those habitats more nearly similar to that of present-day northern coniferous forests. Glacial retreat was followed by migration of hemlock northward just as other floral elements, better suited to cooler climates, migrated northward. In this migration disjunct stations were left both in glaciated and unglaciated areas of Indiana. Miss Parker (23) maintains that Indiana was not in the main path of migration of hemlock from its southern Appalachian haven during the glacial period. This may be true, but the evidence upon which her conclusions are based is not entirely trustworthy. Her conclusions are based upon "The absence of pollen (hemlock) in the bottom of the bog" mentioned above (one in Porter County (Houdek, 16) and one in Steuben County, its scarcity in the upper part, and its absence in other peat bogs south of these two. She concludes that this indicates "that this species was not a member of the northern vegetation that retreated northward with the melting of the glacier." In the first place, it should be pointed out that data have been published for but two other bogs in Indiana. In one of these, the Merrillville bog in Lake County, no attempt was made to differentiate pollen of Tsuga from what was listed as "unknown species". In the second place, it is generally recognized by pollen workers that pollen of Tsuga was not preserved from decomposition under the conditions that prevailed in most bogs during deposition of peat. No data from Indiana are available south of the northern tier of counties. Whether Indiana was or was not in the main path of northward migration of hemlock, we were at least within the fringe of this movement, and, so, Indiana again became a critical botanical area, west of which the hemlock either did not go or at least has not survived to the present.

White Pine (*Pinus strobus* L.), fairly general over Indiana in early post glacial times, if we are to judge from the fossil pollen record from bogs, has left today but a few stations as mementos of its former distribution. Only one of these, that in the Pine Hills area of Montgomery County, presents any evidence of being able to maintain itself. In one other station, that near Merrillville (Lindsey, 19), it is likely to be displaced ultimately by broad-leaved trees, in this case oaks, thus giving us nearly the final scene of the drama begun thousands of years ago

when broad-leaved trees moved northward behind the phalanx of conifers following the retreating ice. Thus, not only has Indiana been a critical botanical area for these competing species in the past, but the age-old struggle is still going on, even though these relict species are fighting losing battles.

Prairie

Indiana again appears as a strongly dynamic botanical area when the limits of the prairies are studied. How many times the prairies have advanced across the state following a long dry period, only to retreat again in front of the advancing forest during a more humid period, no one can tell. But the evidence is unmistakable that in this ever-continuing struggle Indiana has been the scene of much vegetational strife in the past.

The chief evidence today is not only the striking lobate appearance of the prairie areas of Indiana, so aptly referred to by Transeau (30) as the "Prairie Peninsula", but the hundreds of small disjunct prairie patches located in many counties of the state. The strategic position of Indiana is shown in the fact that here we are on the eastern limits of present-day paririe. From the standpoint of plant geography prairies occur under two sets of conditions in Indiana. In the northwestern corner of the state they occur in a very lobate distribution and under a set of climatic conditions which make them climax for the area, and here we find the margin of the prairie today. But farther east, and in hundreds of sites scattered well throughout glaciated portions of the state and, to some extent even in unglaciated portions, we find disjunct prairie patches maintaining themselves under climatic conditions which favor the forest as a climax. These patches are able to maintain themselves for local edaphic, physiographic, or artificial (man-made) reasons and thus represent relics of a former prairie extensive over this region when much drier conditions prevailed. Farther east, in Ohio, Transeau (30) has shown that prairie communities are now limited to sites known to have been prairie at the time of the early settlers and are, thus, only relic patches. Indiana is a critical botanical area, not only on the prairie margin and on every site where relic prairie patches occur, but also we find that we are on the eastern limits of the necessary set of climatic conditions which will permit prairie indicators to invade openings in forest areas. Transeau (30) has shown that prairie species do not invade forest openings in Ohio, but farther west in Illinois and Iowa invasion of secondary forest communities by the prairie is more common. In Indiana probably the most frequent prairie invader of forest communities following cutting is *Andropogon scoparius*. Another prairie species, found much less frequently invading forest communities and limited apparently to sandy ridges dominated by black oak, is the side-oat grama grass, *Bouteloua curtipendula* (Mx.) Torr.

When soil conditions in sites occupied today by prairie indicators are taken into account, it is seen that prairie associations occur on all sorts of soil so that edaphic factors can hardly be considered as determiners. They occur on soils ranging from light sandy to heavy clay, even the extremely finely divided clay soils of the Illinoian drift, and

under physiographic conditions ranging from the level plains of the northern part of the state to upland ridges of the Knobs area in the south central part. It is apparent that civilization and climate, especially rainfall, are the chief determining factors. A study of the rainfall and relative humidity maps prepared by Visher (32) show that precipitation is less in prairie areas than in those bordering them. This is true of average annual, average winter, and average summer precipitation though the prairie area receives a greater percentage of the total rainfall during the growing season than other areas of the state. As Transeau (30) has shown, the forest climax invaded by prairie communities is always oak-hickory and never beech-maple. This is in accord with the conclusion that climatic factors are more important prairie determiners than soil factors. Oak-hickory is the most xerophytic of the forest climax associations occurring in Indiana. Beech-maple occurs on sites sufficiently mesophytic to permit other species to crowd out prairie species, and, hence, we find prairie species invading those forest areas most nearly climatically like the true prairie. Transeau has also pointed out that rainfall is notably irregular in its areal distribution in the prairie areas, some areas being affected one year and others in other years. Irregularity of rainfall is a matter of very much greater critical importance to plants than average rainfall, and this irregularity, much more than averages, becomes a determining factor in prairie limitation.

A number of plants typical of the prairie, and to be looked upon as prairie indicators, reach the eastern-most limits of their range in Indiana, i.e., *Amorpha canescens* Pursh., *Brauneria pallida* (Nutt.) Britton, *Coreopsis palmata* Nutt., *Helianthus rigidus* (Cass.) Desf., *H. Maximiliani* Schrad., *H. petiolaris* Nutt., *Petalostemon candidum* Mx., *P. purpureum* (Vent.) Rydb., *Solidago glaberrima* Martens, *S. longipetiolata* Mack. and Bush, and *Stipa comata* Trin. and Rupr.

Climax Forests

How really critical Indiana is as a dynamic botanical area is impressed upon the student of Indiana plant geography when an attempt is made to classify the forest types. Any classification that is not based upon detailed quantitative analysis from a successional point of view can have only temporary value because forests change as they develop from youth to maturity. In dynamic plant geography the term "climax" is applied to the ultimate type of vegetation which will be supported and permanently maintained by the climate of an area. In every case the succession moves toward the highest degree of mesophytism capable of being supported by the climate of the area. It makes no difference whether the local edaphic conditions begin with the hydrophytic side of the sequence or with the xerophytic side, the succession in either case procedes toward mesophytism. Our studies (Dr. J. E. Potzger's and mine), based upon detailed quadrat analyses and following the conceptions of Clements (7), lead us to the conclusion that all of the types of forest communities occurring in the state may be reduced to three climax forest types, viz., beech, beech-maple, and oak-hickory. In addition, we have recognized relics of the hemlock-white pine-northern hardwoods forest in the relic colonies of hemlock, hemlock-white pine, and

white pine (Friesner and Potzger 9, 10, 11) found in a few disjunct areas within the state. The presence of these northern relics of a former climatic climax are living evidence of change in climate in post-glacial times, and their continuation in the particular sites where they now occur is due to the fact that local conditions of soil and microclimate permit them to survive in competition with the sea of vegetation in which they are but isolated islands, thus making their borders critical zones in Indiana vegetation.

The best evidence of vegetational struggle and the critical character of Indiana as a plant habitat comes to light when detailed study is made of the content and environmental conditions attending the beech-maple and oak-hickory climaxes. Beech-maple occurs as the climatic climax throughout most of the southern four-fifths of the state, but, as we travel northward, we find that roughly north and west of the Tippecanoe River the forests change to chiefly oak and hickory, while beech-maple almost entirely disappears. When we plot the line of differentiation between beech-maple climax and oak-hickory climax on the map of the state, we find that this almost exactly coincides with the zone in which the annual average rainfall changes from 38 inches to 35 inches (Visher, 32), and practically half of the oak-hickory climax area receives only 33 inches of rainfall annually. Rainfall during the growing months of June, July, and August also is the lowest here of any area in the state. Summer rainfall may not be so important as total rainfall for trees in this region of little relief so far as mere survival is concerned, but it is important from the standpoint of amount of growth, and this, in turn, affects vigor and, ultimately, survival.

In the southern four-fifths of the state beech-maple occurs as the climatic climax, but as Potzger (26) has shown, oak-hickory occurs on sites which are more xerophytic and beech-maple on sites more mesophytic. In such areas oak-hickory is always preclimax. We have quadrat studies of a considerable number of oak-hickory associations in which there are to be found no beech or maple seedlings. On these more xerophytic sites oak-hickory reaches an edaphic climax which will likely remain for a long period of time until edaphic conditions change. But, since edaphic conditions change more rapidly than general climatic conditions, and since the general climate supports beech-maple as a climax, we must classify oak-hickory here as preclimax to beech-maple. The situation with regard to oak-hickory here is quite different from that in the extreme northern part of the state. Oak-hickory in the southern part of the state is there chiefly for edaphic reasons and not for general climatic reasons, while they occur in the northern part because the general climate will not support a more mesophytic association. In the northern part of the state, oak-hickory occupies most of the forest sites, and all of those which have reached the climax condition so far as mesophytism is concerned. Beech and maple are seldom found in this oak-hickory area and then only on sites which are more moist than that which is climax for the area.

On the other hand, in the southern or beech-maple area, there are sites where the mature stand may be oak and hickory and the reproduction chiefly beech and maple, in which case it is clear that oak-hickory

is preclimax, while beech-maple is climax. In no case have we observed beech-maple as a mature stand with oak-hickory reproduction. Many of the finest oak-forests in Indiana, and those as nearly virgin as any to be found, such as Nash's woods in Posey County (Cain, 6) and Donaldson's woods in the Spring Mill State Park (Cain, 5), comprise considerable beech and maple and the reproduction in them is chiefly beech and maple, indicating again that oak-hickory must be preclimax in these areas. Equally fine and equally nearly virgin oak areas on other sites, such as the Mantell woods in Dubois County, have no beech-maple reproduction, and on these sites oak and hickory will probably enjoy such a long period of dominance as to become essentially climax. Under such conditions they would be looked upon as subclimax. (Potzger and Friesner, 24).

Studies of soil moisture and evaporation show very definitely that degree of mesophytism is the chief determining factor between these two associations on soils and in climates otherwise suited for either of them. Not only is the moisture content of the soil consistently lower in oak-hickory than in beech-maple sites, but also the evaporation demands made upon the plants for water are higher in oak-hickory. Studies of herbaceous flora growing in oak-hickory and beech-maple communities also lead to the same conclusion regarding higher degree of mesophytism in beech-maple communities than in oak-hickory. The herbaceous flora of beech-maple is decidedly vernal (Esten, 8) in character, while that of oak-hickory is much more definitely aestival and even more autumnal.

The only other climax forests of any appreciable consequence in the state are modifications of the above two, i.e., beech without the maple. Beech with a long subclimax of beech and white oak are the final forest stages on the finely divided clay soil forming the Illinoian drift of the Flats areas in southern Indiana on each side of the Knobs area. Beech may also be climax on similar sites wherever they may occur when the water table is not far below the surface. As Miss Braun (4) has shown, pin oak, sweet-gum, elm, red maple, and over-cup oak form prominent earlier successional members in these Flats communities.

Gordon (13) shows the mixed mesophytic forest identified in Ohio by Sampson (27) as a climax forest on his recent map of "major vegetation areas of Indiana". His conclusion as to the mixed mesophytic forest being climax or even dominant in the Knobs area of Indiana will not stand when based upon detailed quadrat studies. We have made detailed studies of a number of areas in the Knobs region of the state, and, while we have found areas containing linden, tulip, elm, walnut, red oak, white oak, black oak, scarlet oak, chestnut oak, beech, and maple, we have yet to find an area in which the dominants and the character of reproduction did not indicate the association to be either beech-maple or oak-hickory. Beech-maple communities contain more tulip, linden, red oak, elm, and walnut than do oak-hickory communities.

Hemlock and hemlock-pine occur in Indiana today only in a very few sites and are unquestionably relics of a former climatic climax. As such, they have been considered earlier in this paper under the heading of "relics".

Again we reach the conclusion that Indiana is today a critical botanical area in the struggle for dominance on the part climax forest associations.

Range Limits

The critical character of Indiana as a botanical area stands out strikingly also when we realize that over 45% of the present-day species are extraneous, i.e., are on the borders of their range in the state. This figure is probably much higher than actual facts would warrant if they were fully known. Unfortunately no data were available dealing with the complete flora of either Kentucky or Illinois. If such were available, no doubt the total number of species listed as occurring on the southern borders and on the western borders of their range in Indiana would be reduced. It is still more striking when we see that within the state are the critical zones marking limits of distribution for species of all types of higher vegetation: ferns, trees, shrubs, grasses, and other herbaceous forms. There are critical zones for northern species on the southern boundary of their range, for southern species on the northern boundary of their range, for western species on the eastern boundary of their range, and for eastern species, both Appalachian and coastal plain, on the western boundary of their range. Then, to climax it all, there are to be found a few endemics known only within the state.

A total of 392 species are on the southern borders of their range in Indiana in our longitude. Some of these are boreal species, but many others merely range to the north of us. Some may reach more southern latitudes either east or west of us but not in our longitude. A study of the intra-state distribution of these species shows that a number of critical zones occur marking the present-day known limits for these plants. Table I will show the critical zones for this group of species.

It will thus be noted that the Lakes area forms the critical zone for nearly three-fourths of the northern plants which are, in Indiana, on

TABLE I. NORTHERN EXTRANEOUS SPECIES

RANGE LIMITS	PERCENTAGES		
	Of Northern Extraneous Species	Of All Extraneous Species	Of All Species
Lake, Porter, and LaPorte counties only	23.00	9.81	4.50
Lakes area generally, exclusive of above	51.74	21.13	11.15
Wisconsin drift plain south of Lakes area	11.75	5.01	2.30
Illinoian drift plain	9.44	4.03	1.85
Unglaciated Area	4.08	1.24	0.80

the southern border of their range. The margins of Wisconsin glaciation and Illinoian glaciation, respectively, are critical zones for most of the remaining species of this group. Checking these critical vegetational zones with zones derived from metereological data, such as average annual rainfall, lowest and highest years of rainfall, length of average, longest, and shortest growing season, summer and winter precipitation, and temperature zones does not show any certain correlation. It appears that character of soil and amount of human interference are the most critical limiting factors. In any case, it is quite clear that somewhere in Indiana there occurs the critical zone delimiting distribution for many plant species of northern distribution.

A study of the intra-state distribution of the 297 species which are on the northern boundary of their range in Indiana shows that approximately 30% of them reach their northern limits in our longitude within the unglaciated portion of the state, chiefly in the Knobs area. Approximately 34% reach their northern limits in glaciated territory below the southern limits of the Wisconsin drift. Sixty-seven per cent of these southern species reach the northern border of their range at or below the southern edge of Wisconsin glacial drift. The remaining 33% reach the northern boundary of their range far in glaciated territory, about half of them reaching the Lakes area and the other half terminating their range in the Wisconsin drift area south of the Lakes area. These results are tabulated in Table II.

TABLE II. SOUTHERN EXTRANEOUS SPECIES

RANGE LIMITS	PERCENTAGES		
	Of Southern Extraneous Species	Of All Extraneous Species	Of All Species
Unglaciated Territory	30.24	9.81	4.50
Illinoian drift plain	34.94	11.34	5.20
Ohio and Wabash River Counties	3.36	1.09	0.50
Wisconsin drift plain south of Lakes area	11.75	3.82	1.75
Lakes area	19.48	6.32	2.90

This analysis reveals five general areas critical for these southern species, viz., (1) the borders of the unglaciated area of the state, (2) areas bordering the lower Wabash and the Ohio rivers, (3) the southern limits of Wisconsin glacial drift, (4) area of Wisconsin glaciation south of the Lakes area, and (5) the Lakes area. Rainfall belts show little correlation with these critical zones. The first four of them fall within the area of the state receiving an average annual rainfall of 40 inches or more, while the last occurs in the area receiving an average annual

rainfall of 33-35 inches. Rainfall, length of growing season, topography, and soil character probably combine to determine available moisture, and this composite of factors probably determines these critical zones.

Western species occurring in Indiana on the borders of their range form the smallest group of extraneous species found within the state. When the intra-state distributions of the 98 species comprising this group are studied, we find several critical zones marking the termini of distribution. Table III will reveal these critical zones and their relative importance.

TABLE III. WESTERN EXTRANEOUS SPECIES

RANGE LIMITS	PERCENTAGES		
	Of Western Extraneous Species	Of All Extraneous Species	Of All Species
Dunes and sandy areas	38.76	4.14	1.90
Lakes area, exclusive of above	16.32	1.74	0.80
Wisconsin drift south of Lakes area	12.24	1.31	0.60
Illinoian drift area	15.30	1.64	0.75
Unglaciated	4.08	0.44	0.20
Western two tiers of counties, exclusive of above areas	6.12	0.65	0.30
Elsewhere, not classified in any of above groups	7.14	0.76	0.35

It is to be noted that over half of these western extraneous species terminate their ranges in our latitude in the Lakes area, most of them in sandy sites. Approximately 67% terminate their eastern ranges north of the south limits of the Wisconsin drift area, while approximately 18% terminate their range south of this drift plain. Approximately 37% terminate their range within the western two tiers of counties.

It is likely that soil character plays the primary role in determining the critical zones for these species. Rainfall appears to play a prominent secondary role because nearly 36% of these plants terminate their range near the border of the zone of 33 inches average rainfall. An additional 27% terminate their ranges near the border of the zone of 35 inches average rainfall.

Eastern species occurring extraneously in Indiana fall mostly into two groups, viz., those characteristic of the Appalachian plateau, and, hence, both eastern and southeastern, and those characteristic of the coastal plain, some of which may range throughout the extent of the Atlantic Coastal Plain. Species characteristic of the Appalachian plateau are, for the most part, trees and shrubs such as the chestnut

(Castanea dentata), scrub pine *(Pinus virginiana)*, cucumber tree *(Magnolia acuminata)*, chestnut oak *(Quercus montana)*, tulip tree *(Liriodendron tulipifera)*, mockernut *(Carya alba)*, laurel *(Kalmia latifolia)*, and deerberry *(Vaccinium stamineum)*. Additional species are given by Parker (23) in her recent analysis of the Indiana flora.

Peattie (21) has listed over 60 species of plants occurring in the Indiana Dunes and elsewhere limited to the Atlantic coastal plain. Miss Hoober (15), in a manuscript not yet published, has listed over 90 species common to Lake, Porter, and Laporte Counties and the Atlantic Coastal Plain. An even larger number of species characteristic of the coastal plain find range limits within the state as a whole. The explanation for coastal plain species finding range limits in Indiana places them in three main groups. McLaughlin (20) and Peattie (21) have pointed out the presence of early post-glacial paths of migration leading into, and terminating for the most part in, the Dunes and Lakes Region of the state. They have also pointed out a path of migration up the Mississippi River, over which a number of species characteristic of the Gulf Coastal Plain have entered the southwestern and southern parts of the state. Pennell (22) has also shown that many species of the coastal plain have migrated both eastward to the coast and westward into Indiana from the Appalachian highlands. These species have terminated their ranges in Indiana, in some cases because they found here the limit of hospitable territory, and in other cases, no doubt, because they have not yet had time to migrate farther.

When the intra-state distribution of these plants, whose western range terminates in Indiana in our latitudes, is considered, we find again a number of critical zones. The Dunes area of the northwestern corner serves as the critical zone for over one-third of the 108 species. Over 57% terminate their ranges within the Lakes area. Over 16% find

TABLE IV. EASTERN EXTRANEOUS SPECIES

RANGE LIMITS	PERCENTAGES		
	Of Eastern Extraneous Species	Of All Extraneous Species	Of All Species
Sand areas in northwestern corner of state	37.00	4.36	2.00
Lakes area generally, exclusive of above	19.97	1.53	0.70
Eastern lobe of Illinoian drift	5.56	0.65	0.30
Unglaciated territory	16.67	1.96	0.90
Western lobe of Illinoian drift	7.41	0.87	0.40
Western border of State	6.48	0.76	0.35
Wisconsin drift plain south of Lakes area	6.41	0.87	0.40
Elsewhere	6.48	0.76	0.35

their critical zone in the unglaciated area of the Knobs region, and these are mostly trees and shrubs. The extremely finely divided clay soils of the Illinoian drift serve as the critical zone for an additional 12%, nearly all of which are herbs. Table IV presents these critical zones and their relative prominence.

Approximately 52% of these species have the western limits of their range in Indiana north of the limits of Wisconsin glaciation, while 30% have their western limits south of this zone.

Lindsey (18) has shown that 41% of our tree species are on the limits of their range in Indiana, and only 10% are found in all botanical areas of the state. This means that one area or another of Indiana becomes the critical limiting zone in the distribution of many of our common tree species. Twenty-six per cent of the tree species are exclusive to single botanical areas of the state.

Trefz (31), in a similar study of our shrubs, has shown that 56% of them are on the limits of their range in Indiana, while 23% occur in all botanical areas of the state. Forty per cent of them are exclusive to single botanical areas. A smaller percentage of the total shrub species than of tree species occur in each botanical area of the state.

Approximately 20 species and varieties appear to be endemic to Indiana. Of these 55% occur only in the Lakes area, 70% are limited to areas north of the southern limits of Wisconsin glaciation, and 15% occur only south of the limits of Wisconsin glaciation.

Comparative Degree of Criticalness in Each Botanical Area

The Dunes and Lakes area possess a larger percentage of the total flora of the state than any other botanical area. This area also is the critical limiting zone for approximately 50% of the extraneous flora of the state, the most of which are species of northern distribution occurring here on the southern border of their distribution. Miss Hoober (15) has shown that approximately 15% of the total Indiana flora is limited in Indiana to this botanical area. The strongest affinities for the flora of this area lie toward the north and northeast with next strongest similarity to the Appalachian mountain flora.

The southern boundary of Wisconsin glacial drift is the critical limiting zone for approximately 25% of the extraneous flora. These species are southern, reaching their northern boundary just south of the Wisconsin glacial boundary or northern, reaching their southern boundary just north of the glacial boundary. Approximately 14% of the extraneous species reach their limits in the Knobs or unglaciated area of the state. The most of these are southern species. Miss Guss (14) has shown that approximately 74% of the Knobs flora occurs in all other botanical areas of the state. Approximately 5% of the total flora of the state is limited in Indiana to this area. These exclusive species are chiefly Appalachian mountain species.

The lower Wabash Valley acts as a critical limiting zone for approximately 2% of the extraneous flora of the state. Most of these are southern and southwestern species, reaching their northern limits here; a few of them are western, reaching their eastern limits here; while a very small number are northern, reaching southern limits here.

The comparative criticalness of these botanical areas of the state is shown in Table V.

TABLE V. COMPARATIVE CRITICALNESS

	Species Reaching Range Limits	Percentage of This Group of Extraneous Species	Percentage of All Extraneous Species
Lakes Area—			
Northern species	293	74.74	31.94
Eastern species	54	57.00	5.89
Western species	54	55.08	5.88
Southern species	58	19.48	6.32
Endemics	11	55.00	1.20
Total	470		51.23
Wisconsin Glacial Boundary—			
Northern species	46	11.73	5.02
Southern species	194	65.18	4.93
Unglaciated Area—			
Northern species	16	4.08	1.24
Eastern	18	16.67	1.96
Western	4	4.08	0.44
Southern	90	30.24	9.81
Endemic	3	15.00	0.33
Total	131		13.78
Lower Wabash Valley—			
Northern	9	2.09	0.45
Eastern	8	7.40	0.40
Western	12	8.57	0.60
Southern	9	2.68	0.45
Endemics			
Total	38		1.90

Summary

1. Prior to glacial time, Indiana formed a part of the area covered by the great Tertiary forest and apparently was not a critical botanical area.

2. With the coming of the glaciers, Indiana became a critical vegetational area because at least the last two ice sheets reached their southern terminals within the state.

3. As the glaciers withdrew to the north and vegetation likewise

returned northward, successive zones in Indiana marked the temporary termini of distribution of many species and hence became temporary critical botanical zones.

4. Fossil pollen obtained from bogs gives us more concrete evidence of the vegetational battle in early post glacial times. From this study we learn that our forests were once strongly coniferous, but, as climates became warmer, deciduous trees advanced from the south crowding out the fir, spruce, white pine, and hemlock in the order named. Indiana was a critical botanical area for these species.

5. The critical character of Indiana as a botanical area stands out strongly in four ways: (a) it is critical today in many places toward the disjunct stations of nearly 50 relic boreal species; (b) it contains critical zones marking the eastern limits of the present-day prairies and also contains many smaller critical areas marking the borders of hundreds of relic prairie colonies; (c) it is critical ground in the determination of borders of forest climatic climaxes, containing the boundary between beech-maple and oak-hickory climatic climaxes as well as hundreds of critical zones of lesser extent marking the borders between oak-hickory pre-climax and beech-maple climax, and (d) finally, within the state are found critical zones marking the boundaries or ranges of over 45% of the species of ferns and seed plants.

6. Southern range boundaries of northern species, northern range boundaries of southern species, eastern range boundaries of western species, and western range boundaries of eastern species all occur within the state and mark zones critical for these species.

7. The Lakes area forms the critical zone for approximately 75% of the northern extraneous species, 57% of the eastern extraneous species, 55% of the western extraneous species, and 20% of the southern extraneous species. The area is critical for approximately 50% of the total extraneous flora.

8. The limits of Wisconsin glaciation constitute the critical zone for approximately 12% of the northern extraneous species, and 65% of the southern extraneous species. More than 67% of these southern extraneous species fail to extend north of the southern limit of Wisconsin glaciation.

9. The Lower Wabash Valley constitutes a limiting zone for approximately 2% of the total extraneous flora.

10. Of the total extraneous flora, 42% is on southern limits of its range, 31% is on northern limits, 11% is on western limits, and 12% is on eastern limits of its range. A little more than 2% is endemic.

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PROGRAM OF THE SECTION ON ARCHEOLOGY

Chairman: GLENN A. BLACK, Indianapolis

1. Indian trade material in the Wabash region. Amos W. Butler, Indianapolis.
2. Preliminary note on the Moravian Mission to the Delaware Indians on White River, Indiana. Paul W. Weer, Indianapolis.
3. Certain southern Indiana sources of lithic artifact material. E. Y. Guernsey, Bedford.
4. The use of copper by the American aborigines. Eli Lilly, Indianapolis.
5. Photography and anthropology. T. B. Noble, Jr., Indianapolis.
6. Anthropological technique. Charles F. Voegelin, DePauw University.
7. Archeological method. Glenn A. Black, Indianapolis.

Dr. Voegelin's paper, "Anthropological limits of language", published in this volume, pp. ..., deals with only one phase of the subject indicated in title No. 6 of this program.

Dr. Black was reelected chairman of this section for 1937.

Certain Southern Indiana Sources of Lithic Artifact Material

E. Y. Guernsey, Bedford

An artifact, as properly defined, is "anything made or modified by human art." A basket woven from reeds, or an arrow in which wood, stone, and feathers are combined to create an implement of warfare are both truly artifacts. In the present discussion we refer solely to such artifacts as have been fabricated from stone—for which no specifically appropriate term has applied. If one may consistently adopt a word coined from combined Greek and Roman roots, the term "lithofact" may perhaps serve our present need.

Since artifacts of stone were required to serve diverse purposes, both utilitarian and decorative or ornamental, the choice of adaptable materials embraced a wide variety of rocks and minerals. The more primitive aboriginal tribes utilized, we may be sure, only such readily available materials as pertained to their local habitat. Those more restless tribes, who were inclined to see the world, and to conquer a part of it, came quite naturally into contact with the sources of supply of other materials—these more appropriate to their needs or more attractive in coloration or texture than were locally available. Such materials, one knows, were often mined or quarried under some sort of mutual agreement. On the other hand, a species of monopoly sometimes existed in respect to the control of the source; thus the resident tribes bartered or exchanged the raw materials, or even finished artifacts, with other alien, tribes.

When one discovers, in Indiana, artifacts of obsidian from the Yellowstone or from Mexico, or of Lake Superior copper, or of Watcree-Catawba quartz, it becomes obvious that two widely separated regions have been linked at sometime or other by tribal contact or intercourse. Until all the facts have been ascertained, however, it cannot be determined whether this contact was direct, as through tribal migration, or indirectly resultant from incidental contact with tribes who possessed these materials.

Many of the extensively utilized lithic materials are, unfortunately, difficult or impossible to localize; they cannot be referred to a precise, or even relative, locality. Generally speaking, the granites, basalts, argillites, and such-like erratics, since they are almost invariably derived from drift-deposits remote from their point of origin, are of no possible value in a study of tribal movement and contact. Conversely, there is an equally extensive range of materials, as the flints, cherts, marbles, hematites, etc., whose sources may be referred to a circumscribed region, or even to a distinctly local geologic horizon. In such case it often becomes possible to follow the intricacies of tribal movement through an observation of the areal distribution of this characteristic lithic material. The problem, here, is sometimes relatively simple, sometimes extremely difficult, since materials from a specific locality may vary so greatly in appearance and character or may even appear very like similar materials of exotic origin; hence it may develop that

their actual placement may be determined only through consistent observation in the field and by precise tests in the laboratory.

In the choice of materials equally available in a specific locality, that is to say in a location where the excellent and inferior are both at hand, the utilization of one or the other material by the aboriginal craftsman may provide as definite an index of cultural advancement or insufficiency as would his relative artistic proficiency or imagination.

The archeological opportunities which are involved in a conscientious study of these diverse lithic materials and their utilization by primitive man are numerous and varied. Such a study, it must be granted, should be combined with an equally consistent study of the related skeletal material in any well-ordered attempt to trace the migratory movement of our aboriginal tribes. It is to this phase, perhaps, that a fuller understanding of the sources of lithic materials may be best applied.

In the museum of the University of Michigan an unusual involvement is illustrated. Here are two banner-stones from the same habitation-site, the forms of which have not been considered as pertaining to an identical culture-group. It is indisputable, however, that the two artifacts have been fabricated from a single block of porphyry—quite probably by the same artisan. The technique employed is identical in each case, and it is highly probable that a microscopic examination would reveal the use of the same abrading-tools.

In Southern Indiana, as is now sufficiently proved, vast quantities of native flint have been quarried, fabricated in part or wholly, and transported to very remote regions. These aboriginal quarries have been the most abundant source, it now appears, of the projectile material utilized by early tribes living east of the Mississippi. Even the prolific quarries of the Flint Ridge region, in Ohio, were evidently far less important. Within an area involving 255 square miles in Harrison and Crawford counties, these ancient quarries may be observed by the hundreds. There are similar quarries, as well, in Meade County, Kentucky, and in other contiguous counties in Indiana, so that it is probable that the areal extent of the quarry region may be found to embrace at least 500 square miles. In some localities the material is so abundant that many acres sometimes appear entirely covered by a compacted mass of weathered and broken fragments, with interspersed broken and rejected projectile points.

It is debatable whether this excellent material should be classed as flint, hornstone, or chert. It is, as a matter of fact, scarcely less pure than the true English flint. It possesses a perfect conchoidal fracture, and lends itself to the creation of blades of remarkable thinness, symmetry, and delicacy. Its color-range is from a faintly pale gray to deep blue-grays which are almost black. Its geologic horizon is within the Mitchell limestone strata of the Mississippian series. In the two Indiana counties mentioned it occurs usually in the form of almost truly spherical nodules varying from an inch to two or three feet in diameter; however, it likewise occurs in thinly stratified deposits, as within Wyandotte cave. It is from its abundance in this cave, in fact, that the name Wyandotte flint has been quite generally applied to the material. There is indis-

putable evidence that it has been quarried, and fabricated in a limited degree, within the cave itself; yet the site comprised one of the least important quarrying locations.

In their extra extension, these flints of the Mitchell formation depart conspicuously from the characteristic form and color displayed in the Harrison-Crawford region. In Lawrence and Orange counties, where the material is usually referred to as Lost River flint, the nodular variety is rarely spherical, though it sometimes occurs in this form in southern Orange County. The stratified form is, in this general region, more chert-like in character than that found farther south, while the nodular concretions are sometimes dark brown, or red-brown, in color, and are highly siliceous.

While it has been long apparent that the preponderance of projectiles found throughout Southern Indiana were derived from the Harrison-Crawford quarries, it is only recently that an attempt has been made to study the wider distribution of the material. This has certainly extended as far to the northeast as the vicinity of New York City, where it has been observed at village-sites within Van Cortlandt Park, at a site at 215th Street, and at several sites on Long Island. There is slight doubt that the eight-thousand-odd flint discs recovered by Moorehead and others from the Mound City Group, in Ohio, are of Indiana origin. The material is rather well distributed along the Ohio River, from its upper tributaries to its mouth. It has been reported from various sites in Kentucky and Tennessee, and probably has a fairly extensive southern distribution. So far as has been observed, it appears infrequently, or not at all, within the Great Lakes region dominated by late Algonquian peoples.

At the several Clarksville sites about the Ohio Falls, and at all other sites observed in Clark County, the Wyandotte flint appears rather abundantly upon the surface, both in worked form, and in its original quarried state. It has not so far appeared, however, within the older deposits of village debris at the Clarksville sites, even though flint blades have been frequently discovered there as burial accompaniments. One may assume that the earlier occupants of the Clarksville sites were ignorant of, or for some reason did not utilize, this excellent material from a nearby source. For this reason it appears possible that the circumstance may possess a certain chronologic value. On the other hand, it is possible that some other reason may be found for its absence.

Of secondary importance to the material we have just described is another occurring in the same region. Projectiles fabricated from it have an extensive distribution throughout southern Indiana and northern Kentucky. It was generously used by the occupants of the Clarksville village-sites. This is an oolitic chert which is quite inferior to the Wyandotte flint. It is compact in texture, yields readily to percussive flaking, though not to pressure flaking, and is not easily spoiled in the process of manufacture. Worked points or blades of the material are rarely notched, and are almost invariably of slender lanceolate form. The worked blades are often of large size, and of excellent symmetry. Under a microscope, these oolitic cherts appear as a compact aggregate of minute, rounded concretions, with which are associated diminutive fossil

organisms. It is, in fact, an impure silica resulting from siliceous replacement within former oolitic limestones. The color-range of the material is from light warm grays to very dark grays, reds, and purple-reds. When the silicification is quite advanced, it is only by means of microscopic examination that its oolitic character may be discovered.

The source of this much utilized material is obviously from the Gasper-Fredonia oolites of Indiana and Kentucky, though it is probable that investigation will disclose a considerable extension of the deposits toward the south. Numerous aboriginal quarries may be observed within the region of the Mitchell limestones in Indiana. They may be expected to appear in Kentucky as well.

Within Wyandotte Cave great quantities of cave-alabaster, or veined calcite, were aboriginally quarried, principally from the enormous stalactitic column known as the Pillar of the Constitution. Many tons of the quarried, but unremoved, material lie at the base of the column. Among this the primitive quarrying-tools of stone and bone are often found. It has been difficult to imagine the feasibility of transporting the quarried material over the long and obstructed avenue which connects with the present cave mouth; but it seems very apparent that a short and direct passage, now closed by fallen debris, was available to the aboriginal quarrymen.

Probably because of its perishable character, but possibly because the quarried material was transported well beyond the region of its source, artifacts derived from this material are among the rarest pertaining to Southern Indiana. A pipe of similar material was recently recovered from a village-site near Memphis, Clark County. Beads and other decorative artifacts are infrequently found which appear to have been developed from it. Until a great many collections have been studied, however, the use and distribution of the material must remain a problem.

Within the region dominated by the Southern Indiana "Knobs," which embraces, also, a considerable extension within Kentucky, there lies the source of various lithic materials which have been adapted to a wide variety of uses, and which have had a widely extended distribution. Among these materials are the so-called Riverside and Kenwood sandstones, of the Knobstone formation, which vary so greatly in texture and coloration as sometimes to be distinguished with difficulty from those of the Chester and other horizons. They have been utilized for mortars, cupstones, abrading-stones, etc., and for the more specialized pipes, gorgets, tablets, beads, and other artifacts characteristic of the region.

Quite easily identified are the widely-utilized lenticular concretions of manganese-iron oxide from the New Providence shale. Such concretions are abundant, both "in situ" and as eroded from the shale strata, in which latter case they appear strewn over the stream-beds. They are, in fact, massive concretions of impure, uncrystallized hematite, brown or kidney-red in color. They are very hard, and consequently are difficult to fabricate. They are the "liver stones" of the English countryfolk, which name conveys a very proper idea of their form and coloration. From this material a large proportion of the celts, grooved axes, and similar implements of regional usage have been fashioned. In addition, its adaptation has extended to include many more delicate artifacts,

some of which have been polished so that they are not easily distinguished from objects fashioned from true hematite. If accidently dropped, the larger artifacts rarely break through, but a fairly thick, bark-like layer of very hard character separates from an inner core, so to speak, of the implement. The enamel-like layer exhibits a polished patina, while the surface of the core appears coated with an efflorescent bloom of yellow pigment. This, in reality, is a limonite. Much of the "red ocher" included with burials at the Clarksville sites, and perhaps also at Indian Knoll, has been derived from these concretions, crushed and macerated. The more brilliant vermillion ochers of the Clarksville sites were probably obtained from the "red keel" deposits in southern Harrison County.

In the vicinity of the Ohio Falls a local variety of lithographic limestone, from the Devonian, has been utilized for the roller-pestles characteristic of the locality. Some of these pestles are of unusual length, and they are often polished. The same material has been adapted, locally at least, to the manufacture of pipes, banner-stones, and a variety of objects of utility and ornament. In the same quarter, the Devonian and Silurian cherts have been extensively utilized for projectiles, those from the former strata being most generally used, since they occur in nodular form. The Devonian coral-reef at the Falls provided the principal source, it is believed, of the small fossils, often polished or perforated, which have had a general distribution along the Ohio. At the base of the Pleistocene deposits at the Falls, the five-foot stratum of erratic boulders provided the source of perhaps all the larger implements locally fabricated from lithics of igneous origin.

At the Clarksville sites, though doubtfully elsewhere, the relatively soft New Albany shale has been utilized for digging implements, for fleshing and skin-dressing tools, and for the numerous disc-like objects of local occurrence whose use is problematical. Slabs of this material, sometimes worked into rectangular or ovoid form, served as a sort of pillow upon which the head was placed as a burial custom. A variety of yellow ocher, impregnated with sulphuric acid, and likewise derived from these shales, was often sprinkled over the pelves in burial, which practice has resulted in the generally complete destruction of this part of the anatomy.

At practically every Clark County site, and often at sites fairly remote from outcrops of the New Albany shale, small or large fragments or sections of fossil wood from the Devonian tree, Callixylon, appear within the village debris. Their use is undetermined, since no objects definitely fabricated from it have been met with. That it has often been broken into small sections by transverse scoring is evident, and that such small sections are occasionally roughly squared indicates that they may have sometimes served as a material for artifact fabrication.

In the Bedford-Bloomington limestone district, where geodes from the Harrodsburg limestone are numerous, the small quartz-crystals of their interior have been used as a tempering material for the aboriginal pottery typical of the region. Wherever they have been so utilized the small crystals are readily apparent under the microscope. A study of many hundreds of sherds from the region discloses the fact that the use of these geodes for tempering material is practically universal. Similar

geodes, appearing in the New Providence shale of the Knobstone, seem not to have been so used; in fact, only shell-tempered pottery has been so far encountered in the region of the Ohio Falls.

Enough has been said to indicate the diversity and the extent of distribution of some of the principal lithic materials characteristic of Southern Indiana. At best, the present study is no more than superficial. It is hoped, however, that it may serve to stimulate an interest in the latent possibilities of the region in so far as this phase of archeologic research is concerned.

The Use of Copper by the American Aborigines

Eli Lilly, Indianapolis

Early explorers in Canada, New England, New York, Virginia, the Carolinas, and Florida, including Alfonso, Allouez, Champlain, De Soto, Heriot, Newport, Raleigh, Ribault, and Verrazano, all report that the Indians were using ornaments and implements made of copper at the time of their earliest contacts (9, p. 46). The Cabots also observed that the natives "had plenty of copper" (1, p. 6).

Had the site of the great prehistoric copper mining industry not been specifically discovered, its whereabouts could almost have been determined from the gradual increase in the quantity of native copper articles found as the Northern Peninsula of Michigan was approached. Since the distance from the source of supply added to the value and appreciation of the red metal, in the eastern and southern portion of the United States copper was largely used for breast-plates, bracelets, beads, ear spools, and other ornaments (3, p. 715), while spearheads arrow-points, and knives were more plentiful nearer the source of supply and show a gradual evolution from the primitive leaf-shaped, through the stemmed, and finally to perfected socketed forms (7, p. 180).

In addition to axes, chisels, "spuds," and levers of copper, many of the latter eighteen to twenty inches long, the Indians manufactured fish hooks and also used thin copper sheets to cover wooden labrets, ear plugs, and other objects such as wolf jaws and beads of shell, wood, or bone. Many such articles are in the archeological collections, the organic material having been preserved throughout many years of burial by the copper carbonate formed from the metal. In the museum of the Evansville College is a fine example of an elaborate copper helmet or head dress.

Many objects of copper have been found in Indiana, but the center of its greatest use was Wisconsin (9, p. 60), as might have been expected from its proximity to the source of supply. The present relative scarcity of these Indian metallic artifices does not give an accurate idea of the numbers posessed by the aborigines, for doubtless many of them, on account of their value, have found their way into the crucibles of the white man (1, p. 20).

Native copper occurs in limited amounts in a dozen localities in the Blue Ridge Mountains of Virginia and in Person and Rowan counties, North Carolina (3, p. 711), in nearly all the states of the Mexican Republic (8, p. 85), and also in New Mexico and Arizona (6, p. 241). Moreover, masses of float copper were present in the glacial drift in Wisconsin, Michigan, Indiana, Illinois, and Iowa (5, p. 685).

But the Lake Superior region was the source par excellence. There are literally thousands of old mining pits and trenches in the Trap Range which extends through Keweenaw, Houghton, and Ontonagon counties in the Northern Peninsula of Michigan (9, p. 42). The same range dips under the water of Lake Superior and protrudes above the surface in Isle Royale (9, p. 14), which seems to have provided richer rewards than

any other locality. In several places in this region great blocks of copper weighing three, four, and even five thousand pounds have been brought to light bearing the tool marks of the aboriginal miners (4, p. 25).

Two methods of mining seem to have been adopted by these prehistoric people: one, following veins of copper into the solid rock by shattering the matrix with fire, water, and mauls, and the other, of trenching through glacial deposits in search of float copper (9, p. 26). The pits, filled with the debris of an untold number of years, after excavation prove to be from four to ten feet deep and in some cases thirty feet across (9, p. 33). The work required to make these pits with the primitive methods at the disposal of the Indians was perfectly colossal. First the rock surfaces had to be uncovered in order to find the veins where the copper occurred in strings, sheets, and variously shaped masses (3, p. 709) enclosed in the tough rock.

The finding of quantities of charcoal in the pits (5, p. 690-91) shows that the rocks were first heated and then water poured upon them in order to fracture them and to make them more easily pounded to pieces with stone mauls. Wooden bowls for carrying and bailing out water have been recovered from rubbish of the pits together with the remains of birch bark baskets used in carrying out waste material. Pieces of timber thought to have been used as skids and ladders have also been unearthed as well as white cedar shovels, resembling the paddles used by the neighboring Indians to this day for propelling their canoes. Copper chisels and wedges have also been found in these old pits (9, p. 45).

As for mauls, they are strewn over the surface of the ground and throughout the debris on the pits and trenches in such quantities that on Isle Royale alone they are estimated to number at least a million, amounting to a thousand tons of material (5, p. 694). The transportation of these mauls alone, from the ancient beach lines and glacial deposits, entailed a terriffic amount of labor. The mauls and hammer stones ranging from one to forty pounds in weight are usually elliptical in shape and are simply unworked cobble stones of granite or other hard material. It is believed that they were held between the hands because there are no traces of grooves for helves or handles (9, p. 33), although in one case a double groove was discovered, which may indicate that it was used by two men working together (9, p. 43).

After wresting native copper from the matrix of these tough rocks, how did the Indians fashion it into tools and into delicate ornaments? Experimenting archeologists have found that untreated copper pounded to a thin edge crumbles, but that, by alternately heating it and dipping it into water, in other words by annealing the metal, it becomes tough and more ductile (9, p. 58-9). This process must have been known to the Indians, possibly developing from finding that copper broken from the rock formations by heating and then chilling with water worked better and more easily than that picked up in the glacial drift.

The aborigines north of Mexico did not mould copper, for even if it could be melted over an open fire, which is doubtful, what material could their crucibles have been made of (7, p. 174)? That the Mound Builders knew and practiced the art of hardening copper so that it was as hard as steel is not true (3, p. 705).

Fortunately metallurgic art has developed to such perfection that none of the above speculations need remain pure theory, for with the microscope it may now be proven that cold-worked copper shows no crystaline structure when polished and etched, being like unprocessed copper nuggets in this respect. It should be observed, in passing, that cold-hammering renders copper harder and more brittle (10, p. 109).

When copper artifacts fabricated by annealing and hammering are polished and examined microscopically, large equiaxed grains appear, and, since mechanical working twists these grains, microscopic examination reveals the method used. Indeed, so accurate have the metallurgists become that, by the appearance of these grains, the temperature attained during the process of making the object can be very accurately determined. Many copper objects of Indian manufacture have been heated to 800°C. (10, p. 111-12), a bright red heat.

Here we have another criterion which archeologists may seize upon to help untangle tribal and cultural problems.

It has been insinuated that some of the most artistic of the copper plates found by Moore in Florida mounds and by Moorehead in the Hopewell mounds of Ohio and the Etowah site in Georgia, originated with Europeans. Happily the science of chemistry has settled that problem beyond all question (6, p. 241). Lake Superior Copper is much purer than is the metal smelted in Europe during the period in question. Lake copper runs from 99.65 per cent to 99.994 per cent pure (6, p. 221). Its content of silver and iron is quite constant, and minute traces of arsenic, nickle, and cobalt are occasionally found, but never lead or bismuth (3, p. 725). European copper is not so pure, and contains ponderable quantities of lead, bismuth, arsenic, and antimony.

It is quite certain that after the discovery the Whites did supply the natives with copper and that the Indians would recover the metal from shipwrecks and capture it on forages of one kind or another, but this material may always be differentiated by the aid of the test tube. In a majority of cases it has been shown to be brass (6, p. 225).

But to return again to the consumingly interesting problem of the ancient mines,—when they were worked, how long they were worked, and by whom? Since early French and Jesuit explorers made no mention of the mining of copper, it is probable that the pits had been neglected and forgotten at that time (2, p. 264). Father Allouez in 1667 found that the savages regarded copper and the region where it was found with the awe and respect due divinity (1, p. 9-10). In addition, the Chippewa knew nothing of mining and had no tradition in connection with it (9, p. 65).

We do know the following:

(1) No mounds or defenses, homes or other traces or evidence of the cultivation of the soil by these old miners have been found (3, p. 707).

(2) Numerous copper articles are found on the village sites and fields of Wisconsin (7, p. 178).

(3) Dr. Warren K. Moorehead took three or four thousand ear spools of copper from the Hopewell mounds of Ohio alone, and a copper axe twenty-two inches long, weighing thirty pounds, as well as many

other copper articles (1, p. 11-12). He found much copper in the famous Etowah mounds of Georgia.

(4) Village sites have been discovered on Isle Royale where potsherds of Woodland type were discovered as well as skeletal material showing a long-headed tendency (9, p. 39); but, since these camps were over two miles away from the pits, they were probably Chippewa sites occupied long after the mines were worked (9, p. 36).

Based upon the foregoing statements and our knowledge of the subsequent invasions and migrations made by various linguistic stocks in that part of the country, may we not hazard a guess that the miners were a part of the older Woodlands groups who must have taken scores and scores of years to have left so many pits and trenches and who traded their copper with the mound-building nations to the south? These people might very well have been driven off by the first northernly incursions of the Siouan stock, led by the Assiniboine or Dakota or Winnebego. These latter were then, in protohistoric times, pushed further to the west by the Chippewa driving in from the east (9, p. 66). The mounds in Wisconsin yielding no copper may have been built by either of the two latter stocks, who probably did not follow their predecessors in the production of that metal.

Thus, before the discovery of America the working of the mines may have ceased, the straining toil stopped, the mauls and hammers been discarded, the smooth stone anvils abandoned, the annealing fires quenched, and the art of fabricating and of burnishing copper with rubbing stones and sand and water forever lost.

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Anthropological Limits of Language

C. F. Voegelin, DePauw University

If one of the mounds of Indiana were to yield a chamber containing elaborate effigies, skeletons oriented in a certain way in burial, semi-precious stones, metals, an altar and other physical remains, the story which such remains had to tell about the culture and the physical type of its inhabitants might be controversial, but no interested scientist would feel that he was without a right to an opinion, to an interpretation. And this feeling of freedom in wandering into a new and complicated realm of data is healthy and entirely justifiable. But, if in the same Indiana mound a tablet were found inscribed with anything more conventional than simple pictures, the possibility of deciphering a language by their own efforts would never occur to interested scientists; if suggested, a likely response would be that the matter is too complicated for the non-specialist. Now this feeling of tabu in respect to linguistic analysis is not healthful, and is based on a confusion of the psychological and anthropological limits of language.

The former are truly formidable, the latter not. One could not delimit in a few hundred words the psychological boundaries of language, because all the problems of learning, thinking, symbolism, and epistomology are involved; on the other hand, it is possible to delimit briefly the anthropological boundaries of language.

Before doing this, it will be well to point out that incomparably fewer factors, and these more clear-cut, are involved in language than in culture. One thinks of grammar as involved and unattractive because one is educated in a tradition (a matter of culture, note) in which every child is required to memorize certain arbitrary "rules" of Latin grammar, and once learned, every "rule" is found to have, as a sort of unpleasant anticlimax, a number of exceptions. This schoolboy Latin assumes the proportions of a deception when it is realized that the thing so painfully studied was never spoken naturally by men and women but was a more or less artificial construction used by pompous Ciceronean rascals.

However pompous, Cicero had a few fundamental choices to make if he wanted to produce any sounds at all. He was doubtless in the habit of sucking air into his oratorical lungs, and after his blood was oxygenated, breathing the air out again. Now sounds can be made just as well while the air is going in,—inspiratory sounds,—as when the air is going out,—expiratory sounds. We think of expiratory sounds as natural for speech because we use them, and even if we hear dozens of different languages spoken we may never hear an inspiratory sound in speech proper. Of course, anyone is apt to draw in his breath sharply in some emotional situation, and in English the exclamation for encouraging a horse is an in-drawn sound. But for their main business most languages get along with expiratory sounds alone and even when the air which sets up the sound vibrations does not come from as deep down as the lungs (e.g., in making the *p*, *t*, *k* sounds), the air puffs outwards from the mouth. Yet inspiratory sounds are also employed

for the main business of languages in a few parts of the world. The Maidu of California have an implosive *b* and *d*; that is, the air does not puff out of the mouth but is sucked in for these sounds, and, in addition, the vowel *e* is commonly made in Maidu while the air is being drawn into the lungs. The Ges languages of South America have an implosive *g*. Languages spoken in a large area in southern Africa have what is commonly called clicks which are inspiratory sounds, sometimes suggesting the crack of a rifle, when a powerful Zulu, for example, sucks his muscular tongue back over the roof of his mouth until the air snaps in.

Now, whether our linguistic hero chooses to use inspiratory sounds or expiratory sounds, there must be something more involved than the air going in and out of the lungs, for this can be done without any sound at all. The next few choices our hero makes determines how these sounds will be made.

If the speaker is a male, a cartilaginous protuberance sometimes called the Adam's apple may be seen in the front of the throat. This, and the less conspicuous thyroid cartilage of the female speaker, locates approximately the position of the voice-box, which is essentially a reed instrument consisting of two parallel muscles, vocal chords, which may vibrate (making voiced sounds) when the air to or from the lungs passes over them, just as the single reed of a saxophone vibrates when a player blows on the mouth piece. But the two muscles in the voice-box have more possibilities of rest and motion than the reed of a saxophone; and, what is more important, perfectly good speech sounds (voiceless) can be made without any motion whatever of these vocal chords, in contrast to the sounds emitting from a saxophone, which are wholly dependent on the vibrations of the reed. The opening between the two muscles is called the glottis. When the glottis is completely open, a considerable breath of air may be forced up from the lungs without causing any movement of the vocal chords, and we can produce, for example, *h* as in "help", *s* as in "sip", or *f* as in "fix". When the glottis is partially open, open at one end, we may speak without voicing, i.e., by whispering. And when the glottis is tightly closed, we may still make voiceless sounds, like *p*, *t*, *k*, which take advantage of the air in the mouth above the closed glottis. But for voiced sounds the glottis must be open to allow the air to pass through, and the vocal chords must be allowed to vibrate. Then instead of making voiceless *s* (sip), we make voiced *z* (zip); instead of voiceless *f* (fix), voiced *v* (vicks); instead of voiceless *p*, *t*, *k*, voiced *b*, *d*, *g;* instead of whispering we talk out loud. Some languages, like Iroquois, which used to be spoken in Indiana, have mostly voiced sounds; most languages, like Miami, also spoken in Indiana, are about evenly balanced between voiced and voiceless sounds; no language uses either voiced or voiceless sounds exclusively. Irrespective of the choice which any particular language may make, all types of speech sounds, except one, can be made both in a voiced and voiceless form. Thus, in English, *m* is always voiced, but in Shawnee it is also voiceless, sounding as though the speaker were clearing his nose of a little irritation (mtekwi, "tree"). The one exceptional type is made when complete closure of the glottis is the definitive characteristic; the vocal chords cannot then vibrate, and the resulting sound is,

accordingly, always voiceless. When the Danish word "hus" is spoken, a consonant is heard between the *u* and the *s*. This is known as a glottal stop and is made by a sudden closure of the glottis which is after a split second opened again so that air may pass through to produce the final *s*. Menominee, Shawnee, and other languages of the eastern woodlands also use this glottal stop for which there is no voiced form; it is always voiceless. For all other types of sounds a choice is offered between the voiced and voiceless forms, and, of course, many languages use both forms of a given sound.

The next fundamental choice is between making (1) an unimpeded sound with air going from or to the lungs, with the vocal chords vibrating or still, depending on which of the choices mentioned above were taken, or (2) an impeded sound. An unimpeded sound is called a vowel, an impeded sound a consonant. For a consonant the impediment may be a complete momentary interruption of the flow of air at one or two points. If the impediment is at the lips, the resulting consonant is *p*; if the tip of the tongue is placed behind the upper teeth, the consonant is *t*; if the back of the tongue is placed on the roof of the mouth to cause the impediment, the consonant *k* will result. In each instance the flow of air is stopped, and this class of consonant is therefore called a "stop" (a "glottalized stop" if the stoppage at the lips, teeth, or roof of mouth is removed simultaneously with the opening of the closed glottis; an "aspirated stop" if the stoppage is followed by a puff of air, i.e., aspiration; a "voiced stop" if the stoppage at points in the mouth is accompanied by continuous vibration of the vocal chords). If, despite the impediment, the flow of air continues, the resulting consonant is called a continuant. Thus, the lower lip may be placed against the upper teeth to impede the flow of air without completely stopping it in making *f* (voiceless) and *v* (voiced), as in the word "five". In making vowels, the tongue is moved about in the mouth, high and low, front and back, changing the size and shape of the resonance chamber and therefore the quality of the vowel; but the tongue never gets close enough to the teeth or to the roof of the mouth to impede air flow. Some languages in the Philippine Islands have only three vowels; most Algonkin languages have four different vowels; Uto-Aztecan languages usually distinguish between six vowels; Swedish has twenty-one vowels, and a still greater number is found in the Sudan region of Africa. A comparable range in numbers of consonants is found between different languages. Polynesian words, like Italian words, sound as though they were chiefly made up of vowels; in Wishram, a language spoken on the Columbia River of Oregon, it is possible to find extremely long words composed entirely of consonants. While consonantic variety in single languages commonly exceeds vocalic variety in a proportion of four to one, no language has yet been reported entirely without vowels.

The last fundamental choice is to decide whether the air is to go out of the nose or out of (or in, if desired) the mouth. Naturally, if the latter is chosen, the mouth has to be open, but for nasal sounds, the nose does not need to be entirely open. Indeed, a slightly stuffed nose improves nasal sounds. The important thing is to get the air into the nasal chamber, and to do this the uvula, that musclar pendant of the

velum hanging from the back of the roof of the mouth, must be down and relaxed. If this musculature is contracted backwards and upwards, the passage to the nasal cavity is cut off, and the resulting sounds are oral. In some languages like English, it does not matter whether vowels are produced orally or nasally. In Iroquois and Siouan and many other Indian languages, it makes as much difference as in French; to confuse nasal with oral vowels is like confusing a high vowel, like *i*, with a low vowel, like *a*, in English (to say "slip" when you mean "slap"). Nasal consonants, like *m* and *n*, are never made with an indrawn breath for purposes of speech. This is surprising since one variety of snoring is essentially an inspiratory nasal consonant, of the continuant sub-class, usually alternating with a moan-like expiratory *m*. The latter (the expiratory *m*) is used by languages all over the world even when other nasal consonants are lacking; the former (the inspiratory *m*), just as easy to produce as its use in snoring shows, has never been reported in actual use for any language. This is one of many instances showing that languages of the world are curiously limited in their variety. The mere production of sounds offers many possibilities which no language has exploited. Rather, certain paths of preference have become well worn. These have been indicated.

From these paths, it would seem, every language chooses its dozen or score or more of sounds, technically known as *phonemes*. Having chosen its phonemes, a language does not use them in isolation but strings them together in certain characteristic units, such as a sentence, or (so far as the speaker is concerned) the minimum unit of isolable meaning, the word. But the linguist spends most of his time with fractions of the word, the stem, which is the kernel of the word (some words like some nuts have more than one kernel), and affixes, the appendages of the stem, one or many little tags placed fore or aft of the stem (prefixes or suffixes) or right in the middle (infixes), breaking the stem apart, as it were. Altogether, a half dozen linguistic units are commonly isolated: (1) the basic sounds known as phonemes, (2) syllables which are in the phonetic sphere more or less what words are in the semantic sphere, a minimum unit for the native speaker, (3) stems, (4) affixes, (5) words, (6) sentences. It is these units which the linguist picks out to describe from the rumble of speech.

But, strictly speaking, speech never rumbles along. It goes along with a rhythm and in music. Technically, this is a matter of accent, and in some languages like English the rhythm, that is, the stress accent, is the most important thing, while in other languages the music, that is, the pitch accent, is the most important thing. The stress or pitch is associated primarily with the phoneme in some languages, and with the syllable, stem, affix, word or sentence in others. In Yuki, a California Indian language, the affix, as a unit, bears a distinctive tone. In Navaho the primary syllables hold the tone of the word while the tones of other syllables are accommodated to that of the primary. In most complicated tone languages, like the African Ibo and Efik, pitch is an inseparable part of the vowel phonemes. In English we have sentence tone as well as word stress. Thus, in asking a question in which every word may be stressed, the last word is spoken in a higher pitch.

Think of the six units of speech mentioned (phonemes, syllables, stems, affixes, words, sentences) as boxes of different shapes and sizes, and then consider the limited possibilities which are offered in manipulating these boxes for grammatical purposes.

1. If they are strung along in a single line, we may say metaphorically that a pitch accent raises a certain box above the line, while a stress accent depresses another box.

2. In compounding we take two or more of the stem-boxes, each of which has a kernel of meaning (as "to come" plus "to sing" which occurs in Shawnee), and we nail the two boxes together (with the meaning in Shawnee, "He comes here to sing", expressed in one word).

3. In affixation, we take little boxes, often a series of them, and tack them (a) exclusively after the stem-box in languages like Eskimo and Tübatulabal (suffixation without prefixation), or (b) we tack them on the front of the stem boxes,—this possibility is limited to the Khmer of southeastern Asia, and even here is accompanied by infixation (prefixation without suffixation), or (c) we tack them on the back as well as on the front of the stem-box (prefixation and suffixation). Many languages of the world tolerate this, but in most of these, as in English, the prefixes (as re- in "reëxamine") may be dispensed with and the word minus the meaning contributed by the prefix may still be used in any sentence in which the word with prefix was used; suffixes (as *-s* in "thinks") are obligatory if the word is to be used in certain sentences (in this instance, in sentences with singular actor). Yet for languages of the Bantu family in Africa and the Athabascan family of America the reverse is true: the suffixes tend to be dispensable, the prefixes obligatory. A final possibility in affixation occurs (d) when we must first saw the stem-box in half and then tack the two halves on each side of the little infix-box. A widely scattered number of languages permit this, including Yana, Chinook, and some members of the Siouan and Athabascan families; our own ancestral Indo-European made use of an infixed nasal which is reflected in English "stand" as contrasted with "stood".

4. Almost every one of even very small linguistic unit boxes is a mosaic of still smaller phoneme-boxes. Very rarely is this mosaic disturbed, but in a few languages like Lutuami of Oregon the phonemes of some unit-boxes may be transposed, the first coming last and the last first (metathesis).

5. Now we are ready for a bit of trick manipulation: we have a stem-box bearing the meaning "to go" and we want to express the meaning "to go along continuously"; so we take out of our store house another identical stem-box and hitch it on the first (reduplication) and find that "to go" plus "to go" means "to go along continuously" in some languages. Reduplication, like other manipulations of linguistic units, may, of course, express a wide variety of ideas. The Salish of Washington and British Columbia and the Polynesian languages of the Pacific Islands are especially fond of reduplication, which is by no means confined to the stem-boxes.

6. To appreciate the second trick manipulation, think of the boxes as having their shape determined by consonants and their color by

vowels. Now it is possible to take a word-box like English "sing" and paint it different colors, having as a result words like "song" and "sung" in which the vowels are changed (ablauted) but the consonants unchanged. It is just as possible to have consonantic ablaut as the vocalic ablaut illustrated for English. Hamitic languages of north Africa and Semitic languages, like Hebrew and Arabic, and the Penutian languages of California, are given to ablaut changes even more than English.

7. The order of the word-boxes is of no importance at all in languages like Latin or Tübatulabal where little affix-boxes are tacked on the stems to indicate what the relationship is between words. But in languages like English or Chinese, which lack the relational tags, the word-box carrying the actor must precede the word-box telling what the actor did ("women wash on Mondays"), but even in such languages freedom in the order of word-boxes is possible ("on Mondays" may precede "women wash").

Every language of the world manipulates its boxes, its linguistic units, within the narrow range indicated. These different ways of manipulating units are called grammatical processes. As a result of these manipulations, certain meanings are expressed which are known as grammatical categories. The extent of grammatical categories is no greater than that of grammatical processes. There is not so much agreement of terminology here, however, and there is a constant temptation to leave the strictly grammatical field and wander off into psychological fog or logical vapors because meaning is involved. Yet grammatical notions, strictly speaking, are pretty well confined to categories suggested by less than ten technical terms. Some of these categories refer primarily to events (verbs), some to things (nouns).

Gender is a classification of things according to some criterion. This happens to be sex (masculine, feminine, and sometimes neuter) in languages we are familiar with as German, Latin, and those of the Semitic group, but outside of this group of languages in the Old World the expression of sex gender is very rare, it is found in only a few isolated American Indian languages (Chinook, Tunica). All the languages of the Algonkin family, and some others, make a distinction between a thing which is alive or mobile (animate) and a thing which is dead or static (inanimate); the gender classification of the African Bantu languages is based on size or shape or texture and, with such criteria, as many as eighteen genders may be isolated.

Case categories are of two types. In one relationships are indicated. Thus the relationship of the nominative case to the event is that of actor, while a thing in the accusative undergoes the event. The second type includes the various locative cases which indicate the position of the thing in reference to the event (in, on, under, above, toward, away from). Finnish is famous for the number of its locative cases; many Indian languages elaborate locative distinctions beyond the wildest dream of a Finn.

The simple distinction between a singular and plural of English is more exceptional than common. Most languages of the world have a dual, as though we had in English in addition to the forms "tree"

(singular) and "trees" (plural) the possibility of yet another form which I shall invent, "treeses" (exactly two trees). Melanesian languages have a trialis, expressing exactly three things. A paucitive, indicating a few, and a collective, indicating a bunch of units, are met with in many languages.

We think ordinarily of three persons, the first person, or person speaking, the second person, or person addressed (you), the third person, or person spoken about; and we know that each of these persons may be mentioned in the singular or plural or other numbers if the language expresses other numbers. But the expression of person can be still further elaborated. Navaho has a fourth person, the less important of two persons spoken about, and the Algonkin obviative is a type of fourth person. Perhaps there is some correlation between languages which have dual number and those which distinguish between a first person inclusive (we, i.e., you and I, including the person addressed) and exclusive (we, i.e., he and I, excluding the person addressed). Demonstrative notions, nearness and farness, visible and invisible, are often associated with the expression of person, most elaborately perhaps in Southern Paiute.

Tense is familiar to us, ordinarily specified for each event, and in written English sometimes elaborated so that one toys with the past of an event to occur in the future (as was said at Gettysburg, "that we here highly resolve that these dead shall not have died in vain"); but for most American Indian languages tense is left to context. Grammatically speaking, the Indians do not worry about time.

While tense is concerned with the relative time of the action, aspect defines the various manners in which the action may be carried out. Thus one may think of bathing as requiring but a moment (momentaneous aspect, "I took a bath"), or as continuing for some time (durative aspect, "I was bathing"). Most Indian languages would not care to say exactly when a deer was grazing on the mountain side; but great interest would be attached to the differences expressed by the terms iterative, inceptive, cessative, distributive which are self-explanatory. Russian has some expression of aspect, but not nearly as many aspectual distinctions are made in any Old World language as in Nootka, spoken on Vancouver Island.

Mode indicates the attitude of the actor or speaker in respect to the event. Thus, I may be in favor of a bath (desiderative, "I want to bathe"), or in phantasy thinking of the comforts of a bath (optative, "Would I were bathing"), or merely toying with the notion (potential, "I could bathe"; dubitative, "I might bathe"), or I might grant your request to bathe (permissive, "You may bathe"), or I might order you to bathe (imperative, "Bathe!"), or merely urge you to bathe (mild imperative, "Do bathe"), or make a general suggestion including myself in the request (exhortative, "Let's bathe"), or I might inquire whether you had bathed (interrogative mode), or my attitude might be definitely that you had not bathed (negative mode). In syntactic mode, the attitude in one phrase of the sentence depends on how events go in another phrase or "clause" of the sentence (for example, conditional mode, "You may put on your new suit if you take a bath"). Algonkin

languages are particularily rich in syntactic mode. American Indian languages are not, on the whole, rich in syntactic mode, but for other grammatical expressions of mode one finds it necessary again and again to translate single Indian words into long English sentences explaining the attitude of the speaker or actor to the event.

Case, as was mentioned above, is a category associated with "thing"; voice is a category associated with event, with verbs; both categories are concerned with relationships. The intransitive voice has a "thing" for actor but no "thing" in the predication as the undergoer of the event ("The man fell down." If "on the ground" is added, the voice is still intransitive, for "the ground" is mentioned as the location of falling rather than being the undergoer of the fall). For transitive verbs, the predication includes a "thing" which undergoes the event ("The man touched the ground"). For passive verbs the undergoer of the transitive is prominently specified and in most languages the actual actor is not mentioned ("The ground is being touched"), but in Algonkin languages the agency of the event is also mentioned ("The ground is being touched by the man"). Other expressions of voice include the mediopassive, indicating that the event is done for the actor (a well-known voice because it occurs freely in Greek literature), a polarity of active and static ("He runs", as contrasted with "He thinks"), an impersonal ("There is singing"), the reflexive ("He touched himself"), the reciprocal ("We touched each other"), the benefactive ("He sang for him"), the causative ("He made him sing").

We may pause here and note that, for grammatical categories no less than for the manipulation of linguistic units (than for the number of these units, than for the fundamental choices of sounds), the range of actual usage for all languages of the world combined never approaches its logical possibilities. For example, we found that in the expression of number some languages made grammatical use of the dual, some of the trialis in addition to the singular and plural with which we are all familiar; but no language has a grammatical means of expressing exactly four things or persons. Since the ceremonial number of so many tribes is four, and it is therefore constantly necessary to say (with an additional word) that four men went, or that they did so and so four times, a compact grammatical expression of this number would be obviously useful. It does not exist. What linguistic variety does exist in languages of the world is to be found within the areas circumscribed above in phonemes, units, manipulation of units, and meanings expressed by this manipulation.

Since linguistic diversity is limited to such a circumscribed sphere, it offers in point of fact less to alarm the non-specialist than the sphere of culture which is much wider and much more difficult to circumscribe. An interested non-specialist who is bold enough to make an interpretation concerning the cultural material which an archeological find reveals has therefore no need to fear the fewer factors and the smaller field of operation implicit in analyzing the linguistic material from the same archeological source.

PROGRAM OF THE SECTION ON BACTERIOLOGY

Chairman: C. A. Behrens, Purdue University

1. Further studies on the immunology of Hemophilus rertussis. H. M. Powell and W. A. Jamieson, Lilly Research Laboratories, Indianapolis.
2. Serological response to oral immunization against colds. H. C. Allisborough and L. C. Morgan, Lilly Research Laboratories.
3. The epidemiology of Brucella abortus (Bang) infection in cattle. Stanley E. Hartsell, Purdue University.
4. Isolation of bacteria and protozoa from termites. P. A. Tetrault, R. L. Phillips, and W. L. Weis, Purdue University.
5. Rabies, preparation of citrated vaccine. C. A. Behrens, Purdue University.
6. Rabies, immunity by means of purified vaccine. C. A. Behrens, J. L. Reeves, and L. B. Schweiger, Purdue University.
7. Titration of gas gangrene antitoxin by an intracutaneous method. H. D. Piersma, Purdue University.
8. The application of Gibson-Brandt volatile-acid method to acetic and butyric acids in fermentation. P. A. Tetrault and J. Hurwitz, Purdue University.
9. Maintenance of antiseptic action by "Merthiolate" as a preservative. H. M. Powell and W. A. Jamieson, Lilly Research Laboratories.

The title of paper No. 9 was received too late to be included in the program published in advance of the meeting.

Dr. H. M. Powell was elected chairman of the section for 1937.

Maintenance of Antiseptic Action by "Merthiolate" as a Preservative

H. M. Powell and W. A. Jamieson, Lilly Research Laboratories, Indianapolis

Following its introduction (1, 2) as an antiseptic in 1931, "Merthiolate" (Sodium Ethyl Mercuri Thiosalicylate, Lilly) has been used in several laboratories for preserving vaccines, sera, and other biological products.

In 1933 we examined by staphylococcal plating methods already described (1) the approximate "Merthiolate" content of commercial typhoid mixed vaccine prepared in 1931. This vaccine was prepared in the usual way and then preserved with "Merthiolate" 1:10,000 and stored at 5° C. for two years. At that time, by the technique described, it produced "clearings" 9 to 11 mm. in width when streaked with a platinum loop on poured *Staphylococcus aureus* agar plates, as compared to "clearings" of 12 to 14 mm. in width produced by fresh "Merthiolate" 1:10,000 solution in similar quantities.

In their comparative studies dealing with vaccine and serum preservatives, Rosenstein and her associates (3) concluded that while both phenol and tricresol preservatives decreased in efficiency during ten months storage at 5° C., "Merthiolate" and mixed "Merthiolate" and phenol preservatives were apparently unimpaired during this time. Results of longer stability tests are believed to be desirable, and such tests have been conducted as follows. Recently we have examined, by staphylococcal test-tube inhibition methods already described (1), the approximate effective "Merthiolate" content of six lots of bacterial vaccine one to five years of age and eight lots of antitoxin one to seven years of age. All of these were regular commercial preparations preserved with "Merthiolate." Some were "house samples" and some had been outdated and returned and hence had been subjected to actual commercial handling for from one to three years.

In these tests the vaccines and antitoxins, along with fresh samples of "Merthiolate" 1:10,000 for control, were diluted with sterile broth so that the original "Merthiolate" content was reduced to a range from 1:50,000 to 1:4,000,000. Staphylococcal[1] inhibitory action of 5 cc. quantities of these various series of dilutions in tubes against one loop of twenty-four hour broth culture of *Staphylococcus aureus* No. 209 was then determined as has already been described. Readings of inhibitions for 24, 48, and 72 hours are shown in Tables I and II. These indicate that "Merthiolate"-preserved vaccines and antitoxins up to three years old exert an antiseptic action which is not substantially different from that of fresh "Merthiolate" 1:10,000 solution. All of the preparations up to three years of age, when diluted on the basis of original 'Merthiolate' content, inhibited Staphylococcus for 24, 48, and 72 hours incubation at dilutions of 1:3,000,000, 1:2,000,000 and 1:1,000,000, respectively. Both

[1]Staphylococcus was selected on account of its intermediate vulnerability to "Merthiolate," diphtheroids being less resistant and pyocyaneus more resistant. See Rosenstein, et al. (3).

vaccine and antitoxin decreased in antiseptic action after five and seven years. Some of the variation in the results tabulated may be due to the slight enrichment of the antitoxin series of tubes with the globulin carried over in accomplishing preservative dilution.

Similar staphylococcal inhibition tests have been applied to one- and two-year-old lots of pertussis vaccine preserved with 0.5% phenol. These vaccines, along with a phenol control solution, were diluted in broth using one part of vaccine to one, two, three, four, and five parts of broth and tested for staphylococcal inhibition. None of the test dilutions showed any inhibition, while the two strongest phenol control dilutions gave complete inhibition for three days. This indicates a rather rapid weakening of the phenol preservative which of course is never very highly inhibitory.

Similar inhibition tests have been applied also to six lots of tricresol-preserved vaccines and antitoxins which were available. The antitoxins contained originally 0.35% alcresta cresol and were seven, eight, and eight years old, respectively, while the vaccines contained 0.3% S. and G. tricresol and were seven, nine, and nine years old respectively. None of these, when diluted with one or more parts of broth, inhibited the staphylococcus, while control cresol solutions, when diluted with three parts of broth, caused inhibition. The cresols as well as phenol are never very highly inhibitory.

As further tests of the remaining vaccines and antitoxins which had shown losses in antiseptic action in the previous experiments, we conducted long-exposure germicidal tests in the ice box using one loop of twenty-four hour culture, diluted 1:100,000, planted into 1 cc. quantities of the undiluted vaccine or antitoxin. Sterility tests of these preparations were made after standing one day, two days, and longer. The results of these tests are shown in Table III. The five- and seven-year-old "Merthiolate"-preserved vaccines and antitoxins contained no viable Staphylococci after standing from two to ten days in the ice box. The one and two year old phenol-preserved vaccine was sterile after one day. The seven year old tricresol-preserved antitoxin did not become sterile in thirteen days.

Although we have not had all the samples of increasingly aged vaccines and antitoxins with different preservatives available for a thorough comparison up to seven or eight years, it appears that "Merthiolate" as a preservative alone maintains its antiseptic action almost fully for three years. At some point between three and five years its antiseptic action is considerably decreased. Seven-year-old "Merthiolate"-preserved antitoxin, however, is still able to sterilize itself of approximately 1,000 to 10,000 Staphylococci per cubic centimeter. Our results, together with those of Rosenstein et al, show that "Merthiolate" as a biological preservative can be depended upon, we believe, better than phenol and tricresol to exert prolonged antiseptic action together with less denaturation than any other antiseptic similarly studied and used.

Conclusions

1. When used as a preservative, "Merthiolate" maintains substantially full antiseptic action for three years.

TABLE I

Staphylococcal Inhibition Tests of "Merthiolate"-Preserved Vaccines to Measure Maintenance of Antiseptic Action

Dilution of Vaccine in Broth to Reduce "Merthiolate" Content to:	Hours of Incubation at 37°C. at Which Bacterial Growth Was Observed											
	24	48	72	24	48	72	24	48	72	24	48	72
	Staphylococcus Vaccine No. 913800 One year old			Staph-Strep Vaccine No. 915521 One year old			Streptococcus Vaccine No. 897174 Two years old			Coli Vaccine No. 896623 Two years old		
1—500,000	–	–	–	–	–	–	–	–	–	–	–	–
1—1,000,000	–	–	–	–	–	–	–	–	–	–	–	–
1—2,000,000	–	–	–	–	–	–	–	–	–	–	–	–
1—3,000,000	–	–	–	–	–	–	–	–	–	–	–	–
1—4,000,000	–	–	+	–	–	–	–	–	–	–	–	–
	Influenza-Pneumo Vaccine No. 887072 Three years old			Typhoid Mixed Vaccine No. 109294 Five years old			Fresh "Merthiolate" 1—10,000 Solution (Control)					
1—50,000				–	–	–						
1—100,000				–	–	–						
1—500,000	–	–	–	+	+	+	–	–	–			
1—1,000,000	–	–	–	+	+	+	–	–	–			
1—2,000,000	–	–	–	+	+	+	–	–	–			
1—3,000,000	–	–	–	+	+	+	–	–	–			
1—4,000,000	–	–	–	+	+	+	–	+	+			

TABLE II

Staphylococcal Inhibition Tests of "Merthiolate"-Preserved Vaccines to Measure Maintenance of Antiseptic Action

Dilution of Antitoxin in Broth to Reduce "Merthiolate" Content to:	Hours of Incubation at 37°C. at Which Bacterial Growth Was Observed											
	24	48	72	24	48	72	24	48	72	24	48	72
	Tetanus Antitoxin No. 909978 One year old			Tetanus Antitoxin No. 913141 One year old			Tetanus Antitoxin No. 895816 Two years old			Tetanus Antitoxin No. 893344 Two years old		
1—500,000	−	−	−	−	−	−	−	−	−	−	−	−
1—1,000,000	−	−	−	−	−	−	−	−	−	−	−	−
1—2,000,000	−	−	+	−	−	+	−	+	+	−	−	−
1—3,000,000	−	+	+	−	+	+	−	+	+	−	+	+
1—4,000,000	−	+	+	−	+	+	−	+	+	−	+	+
	Erysipelas Serum, Conc. No. 884486 Three years old			Normal Horse Serum No. 876720 Five years old			Diphtheria Anti toxin No. 33095 Seven years old			Tetanus Anti toxin No. 31457 Seven years old		
1—50,000				−	+	+	−	−	+	+	+	+
1—100,000				−	+	+	−	+	+	+	+	+
1—500,000	−	−	−	−	+	+	+	+	+	+	+	+
1—1,000,000	−	−	−	−	+	+	+	+	+	+	+	+
1—2,000,000	−	−	+	+	+	+	+	+	+	+	+	+
1—3,000,000	−	+	+	+	+	+	+	+	+	+	+	+
1—4,000,000	−	+	+	+	+	+	+	+	+	+	+	+
	Fresh "Merthiolate" 1—10,000 Solution (Control)											
1—500,000	−	−	−									
1—1,000,000	−	−	−									
1—2,000,000	−	−	−									
1—3,000,000	−	+	+									
1—4,000,000	−	+	+									

TABLE III

Self-sterilizing power of aged vaccines and antitoxins, the preservatives of which made weak showings in previous tests

Preservative	Biological	Age in Years	Sterility of Staphylococcus Inoculated Biological After (days):					
			1	2	6	8	10	13
"Merthiolate"	Staphylococcus vaccine No. 35569	5	+	−	−			
	Typhoid vaccine No. 108256	5	+	+	+	−	−	
	Diphtheria antitoxin No. 32658	7	+	+	+	+	−	−
	Tetanus antitoxin No. 33328	7	+	−	−			
Phenol	Pertussis vaccine No. 915591	1	−	−				
	Pertussis vaccine No. 898469	2	−	−				
Tricresol	Streptococcus antitoxin No. 105286	7	+	+	+	+	+	+
	Streptococcus antitoxin No. 32656	7	+	+	+	+	+	+

In this test 1 c.c. quantities of the various biologicals were planted with a loop 1-100,000 dilution of 24-hour broth culture Staph aureus No. 209, and then stored in the ice box. These preparations were then tested for sterility by planting a loop of each into the usual fermentation tubes of infusion broth, etc.

2. Although showing a decrease in antiseptic action after three years, "Merthiolate"-preserved antitoxin at the end of seven years still maintains a certain degree of self-sterilization.

References

1. Powell, H. M. and Jamieson, W. A., 1931. Merthiolate as a germicide. Amer. Journ. Hyg. **13**:296-310.

2. (a) Jamieson, W. A. and Powell, H. M., 1931. Merthiolate as a preservative for biological products. Amer. Journ. Hyg. **14**:218-224.

(b) Morgan, L. C., Jamieson, W. A., and Powell, H. M., 1933. Merthiolate as a preservative for biological products. II. The production and preservation of diphtheria toxoid. Journ. Immunol. **25**:121-126.

(c) Powell, H. M., Jamieson, W. A., and Jones F. G., 1933. Merthiolate as a preservative for biological products. III. Action of Merthiolate on bacteriophage. Journ. Immunol. **24**:185-192.

3. (a) Rosenstein, C. and Levin, I., 1935. The bactericidal and antiseptic action of preservatives frequently used in biological products, and the effect of these preservatives on the potencies of the products. Amer. Journ. Hyg. **21**:260-279.

(b) Falk, C. R. and Aplington, S., 1936. Studies on the bactericidal action of mixtures of phenol and Merthiolate. Journ. Bact. **31**:8.

(c) Falk, C. R. and Aplington, S. P., 1936. Studies on the bactericidal action of phenol and Merthiolate used alone and in mixtures. Amer. Journ. Hyg. **24**:285-308.

The following, included in the titles of papers in the foregoing references, is a trade-mark which identifies a product of Eli Lilly and Company: "Merthiolate."

PROGRAM OF THE SECTION ON BOTANY

Chairman: NAOMI MULLENDORE, Franklin College.

1. Studies in Indiana bryophytes. Winona H. Welch, DePauw University.
2. First record in North America of the chloromonad flagellate, Merotricha capitata. C. Mervin Palmer, Butler University.
3. Notes on Indiana grasses for 1936. J. E. Potzger, Butler University.
4. A plant sociology of the herb layer in two types of central Indiana forests. J. E. Potzger and R. C. Friesner, Butler University.
5. Winter injury to trees and shrubs of Purdue University campus. A. T. Guard, Purdue University.
6. Unusual gladiolus hybrids resulting from species crosses. W. P. Morgan, Indiana Central College.
7. A quantitative study of the phytoplankton of the White River canal, Indianapolis, Indiana. E. Charlene Coffing, Butler University.
8. Some unusual plant and habitat relationships on Mackinac Island, Michigan. J. E. Potzger, Butler University.
9. A preliminary ecological survey of a typical Illinoian Till Plain forest in Jennings County, Indiana. Scott McCoy, Butler University.
10. Notes on Ruellia strepens, and its so-called variety cleistantha Gray. Scott McCoy, Butler University.
11. Observations on the methods of stipe-formation in Stemonitis and Comatricha. William D. Gray, University of Pennsylvania.
12. Some unsolved problems of fungus physiology. C. L. Porter, Purdue University.
13. Fungus growth as affected by varying concentrations of salts. R. B. Zumstein, Purdue.

Two papers published in this volume were read before the Botanical Section at earlier meetings. Their titles are as follows:

Some physical features associated with the pliability of wood. J. E. Potzger and Florence Geisler.

Soil acidity and hemlock reproduction in relic colonies in Indiana. J. E. Potzger and Ray C. Friesner.

Dr. C. L. Porter, of Purdue University, was elected chairman of the section for 1937.

Studies in Indiana Bryophytes

WINONA H. WELCH, DePauw University

The mosses used in this study are Indiana collections in herbaria in the following institutions: Indiana University, Purdue University, DePauw University, Field Museum of Natural History, University of Illinois, University of Wisconsin, and University of Chicago, and in personal herbaria of the following: Chas. C. Deam, J. P. Naylor, Seville Flowers, Betty L. Wilson, and the author. Chas. C. Deam, William D. Gray, Earl L. Harger, Jr., and Harriet Gragg Winch have kindly presented many collections to the writer.

The nomenclature of Tetraphis, Bryoxiphium, and Fissidens is that of "The Moss Flora of North America north of Mexico," A. J. Grout; of Polytrichum, "The Polytrichaceae of Western North America," T. C. Frye; of Pogonatum, Catharinea, (except *C. plurilamellata* which is according to "Manual of Mosses of Western Pennsylvania," O. E. Jennings), Buxbaumia, and Webera, of "Mosses with Hand-Lens and Microscope," A. J. Grout.

The distribution of each species is based largely upon Indiana specimens examined by the author and is shown by the list of counties in which collected. The asterisk preceding the name of a county indicates that the species has been reported from that locality according to published records but not studied by the author.

The asterisk following the name of a species or a variety is an indication that, according to available literature, this is the first published record for Indiana.

TETRAPHIDACEAE

Tetraphis pellucida Hedw. (*Georgia pellucida* Rabenh.) (Figs. 1, 2.) Stems 1-2 cm. high, always some bearing terminal gemmiferous cups; peristome teeth 4, narrowly triangular. *Hamilton, Jasper, Lake, Laporte, Marshall, Montgomery, Orange, Parke, Porter, Putnam, and Steuben counties.

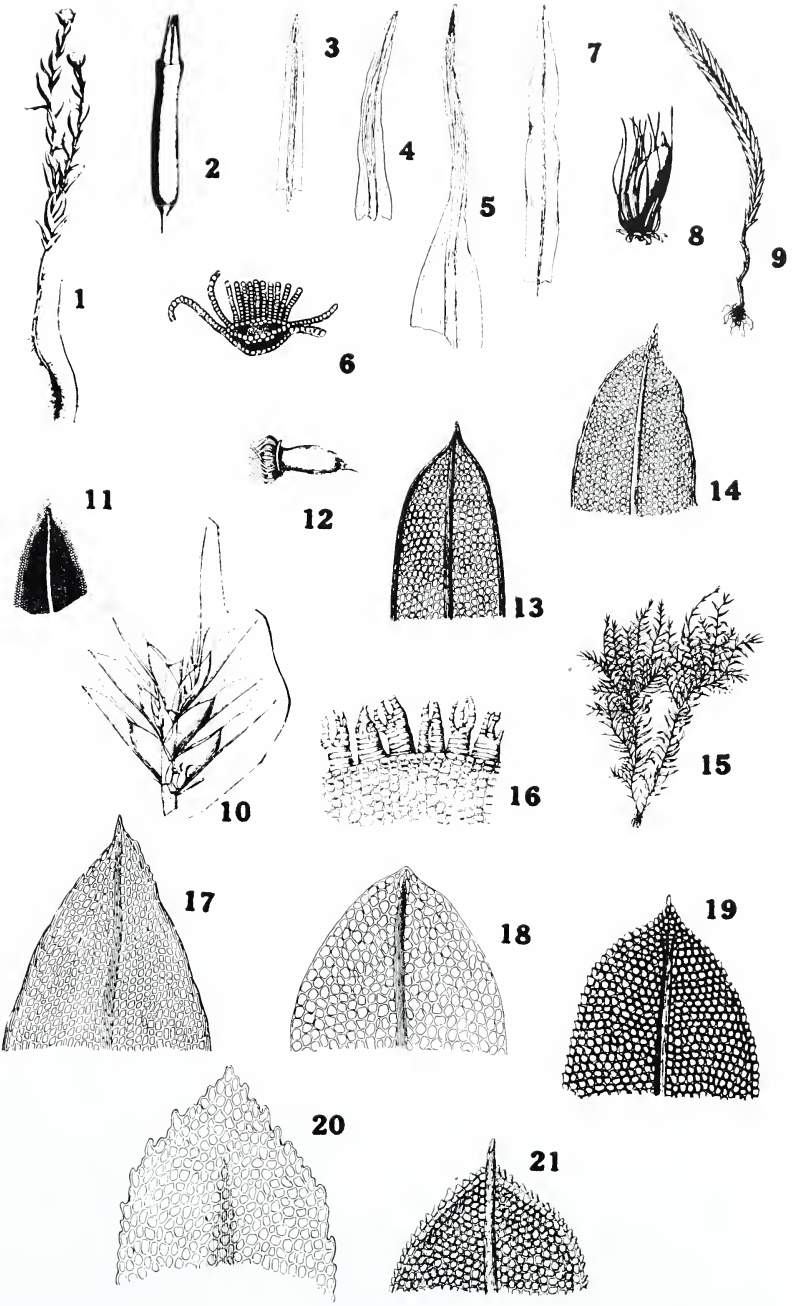
POLYTRICHACEAE

Leaves usually narrow, with lamellate costa; capsule on a long seta, large, cylindrical, or prismatic with 4-6 angles; calyptra spinulose at apex, or with few to many hairs.

1. Leaves bordered, lamellae on upper surface 18 or less; capsule terete; calyptra with few or no hairs; peristome teeth 32.....*Catharinea*
   Leaves not bordered, lamellae on upper surface 20 or more; capsule cylindrical, or prismatic with 4-6 angles; calyptra densely hairy; peristome teeth 32-64.....2
2. Capsule terete; peristome teeth 32.....*Pogonatum*
   Capsule 4-6 angled; peristome teeth generally 64.....*Polytrichum*

Catharinea

1. Costa and lamellae covering about ¼-¼ of upper leaf-width; lamellae 3-6 in number, 3-6 cells in height; upper leaf cells 15μ-25μ in diameter.....*C. undulata*
   Costa and lamellae covering ¼ or more of upper leaf-width; lamellae usually more than 6, more than 6 cells in height; upper leaf cells 7μ-15μ in diameter.....2
2. Lamellae covering ¼-½ of upper leaf-width, 5-8 in number, 6-8 cells high; upper leaf cells 10μ-15μ in diameter.....*C. angustata*
   Lamellae covering about ⅔-⅘ of upper leaf-width, 7-12 in number, 8-14 cells high; upper leaf cells 7μ-13μ in diameter.....*C. plurilamellata*



Figs. 1-21

C. **angustata** Brid. (Fig. 3.) Carroll, Clark, Crawford, Delaware, Elkhart, Floyd, Gibson, Henry, Jackson, Jasper, *Jefferson, Knox, Kosciusko, Lawrence, Madison, Marshall, Martin, Monroe, Montgomery, Owen, Parke, Porter, Posey, Pulaski, Putnam, Scott, Steuben, Vermillion, *Vigo, *Wayne, Wells, White, and Whitley counties.

C. **plurilamellata** Jennings.* (Fig. 3.) Carroll county.

C. **undulata** (L.) Web. & Mohr. (Fig. 7.) Allen, Brown, Carroll, Decatur, DeKalb, Delaware, Elkhart, Floyd, Jasper, Jefferson, Lagrange, Laporte, Lawrence, Monroe, *Noble, Orange, Parke, Porter, Posey, *Pulaski, Putnam, Shelby, Steuben, Wabash, Washington, *Wayne, Wells, and Whitley counties.

Pogonatum

1. Leaves lanceolate-subulate, serrate; capsules usually more than 2:1, usually straight, occasionally inclined or drooping; calyptra gray.....*P. brevicaule*
   Leaves lingulate, blunt, entire; capsules less than 2:1, usually curved, and unsymmetric at base; calyptra tawny-red-brown.....*P. brachyphyllum*

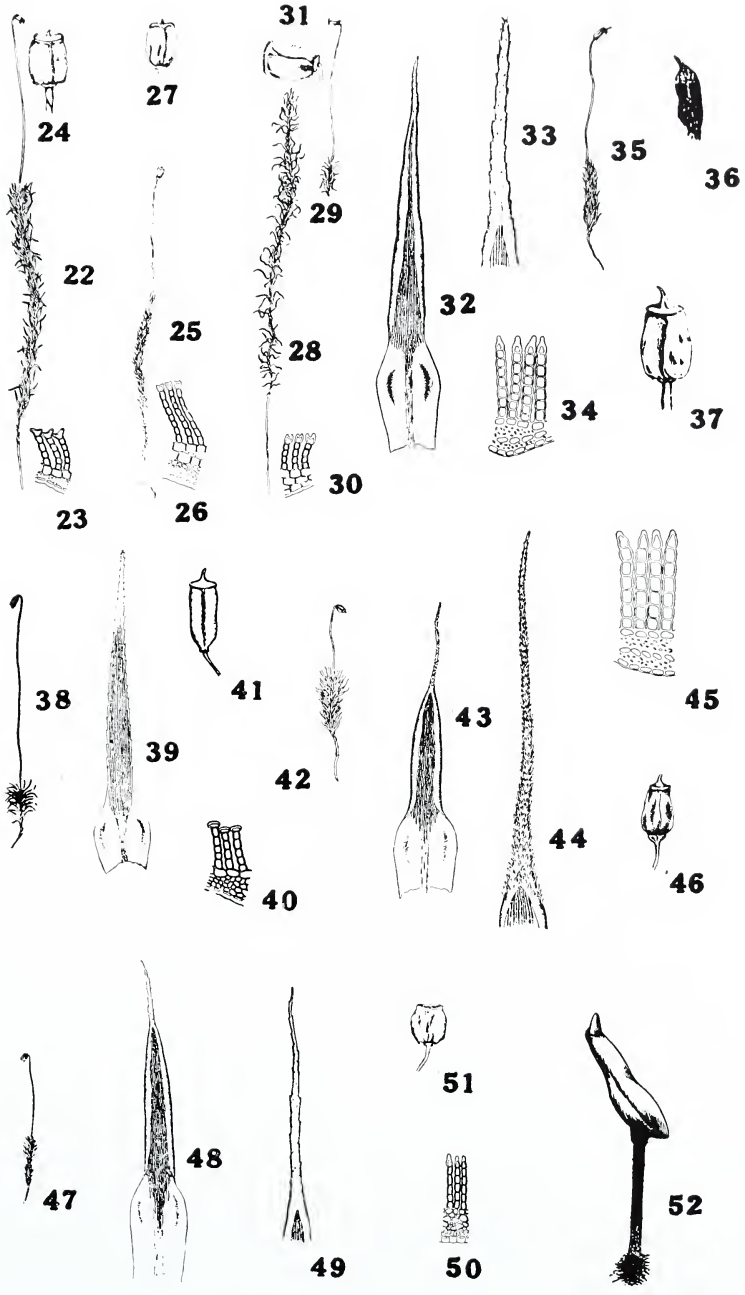
P. brachyphyllum (Michx.) Beauv. Monroe and Putnam (?) counties.

P. brevicaule (Brid.) Beauv. Brown, Floyd, Laporte, Monroe, and Putnam counties.

Polytrichum

1. Leaf margin serrate to sheath or nearly so, plane or erect; leaves sharply pointed, costa excurrent in a red dentate point about 1 mm. in length.....2
   Leaf margin entire, incurved; leaves sharply pointed, costa excurrent as an arista 5
2. Plants 3-6 cm. high; leaves spreading when moist, erect-flexuous when dry, cells in middle of sheathing base longer than wide as 3-4:1; lamellae about 50, 5-7 cells high, marginal cells oval or flattened, thickened, much larger than the others, broader than long as 1½-2:1; capsule sharply 4-5 angled, rarely 6-angled, longer than wide as 2-2½:1.....*P. ohioense*
   Plants 5-45 cm. high; upper leaves squarrose or recurved when moist, erect and appressed when dry (with exception of var. *uliginosum*), cells in middle of sheathing base linear as 10-20:1; lamellae about 60, 4-6 cells high, marginal cells notched or bicuspidate in cross section, broader than others; capsule sharply 4-angled, more or less cubical as 1¼-1¾:1.....3

Figs. 1-21. Figs. 1, 2. *Tetraphis pellucida* (From Bry. Eur., pl. 196). Fig. 1. Sterile plant bearing gemmiferous cups, enlarged. Fig. 2. Capsule and peristome of four teeth, enlarged. Fig. 3. *Catharinea angustata* (From Grout, M. H. M., fig. 14). Leaf, x 4.5. Figs. 4-6. *Catharinea plurilamellata* (From Jennings, Mosses W. Pa., pl. 27). Figs. 4-5. Leaves, x 7.1. Fig. 6. Cross section of stem leaf, x 47.5. Fig. 7. *Catharinea undulata* (From Grout, M. H. M., Fig. 14). Leaf, x 4.5. Fig. 8. *Webera sessilis* (From Grout, M. H. M., fig. 20). Capsule surrounded by perichaetial leaves, x 2.8. Fig. 9. *Bryoxiphium norvegieum* (From Bry. Eur., pl. 195). Sterile plant, enlarged. Figs. 10-12. *Fissidens adiantoides* (From Bry. Eur., pl. 105). Fig. 10. Section of stem, showing the split appearance of basal portion of leaves, enlarged. Fig. 11. Leaf apex, enlarged. Fig. 12. Capsule and peristome, enlarged. Fig. 13. *Fissidens bryoides* (From Bry. Eur., pl. 101). Leaf apex enlarged. Fig. 14. *Fissidens bryoides*, var. *incurvus* (From Bry. Eur., pl. 99). Leaf apex, enlarged. Figs. 15, 16. *Fissidens Julianus* (From Bry. Eur., pl. 108). Fig. 15. Sterile plant, x 0.6. Fig. 16. Portion of peristome, enlarged. Fig. 17. *Fissidens minutulus* (From Sull. Icones Musc., pl. 24). Leaf apex, enlarged. Fig. 18. *Fissidens obtusifolius* (From Sull. Icones Musc., pl. 22). Leaf apex, enlarged. Fig. 19. *Fissidens osmundoides* (From Bry. Eur., pl. 103). Leaf apex, enlarged. Fig. 20. *Fissidens subbasilaris* (From Sull. Icones Musc., pl. 26). Leaf apex, enlarged. Fig. 21. *Fissidens taxifolius* (From Bry. Eur, pl. 104). Leaf apex, enlarged.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Figs. 22-52

3. Leaves appressed when dry; capsule 1¼-1½:1.....4
   Leaves spreading-recurved when dry, lamellae 4-6 cells high; inner perichaetial leaves not exceeding the foliage leaves; capsule 1½-1¾:1, beak of operculum slightly curved.....*P. commune*, var. *uliginosum*
4. Lamellae 4-6 cells high; inner perichaetial leaves not exceeding the foliage leaves; beak of operculum slightly curved.....*P. commune*
   Lamellae 6-9 cells high; inner perichaetial leaves very long, exceeding the foliage leaves; beak of operculum straight.....*P. commune*, var. *perigoniale*
5. Arista red, rarely somewhat colorless at tip, rough, ½-1½ mm. long; lamellae 4-7 cells high, marginal cells longer than wide, ovate or flask-shaped.....6
   Arista hyaline, rough, up to 3 mm. in length; lamellae 4-7 cells high, marginal cells longer than others, ovate or flask-shaped, thickened, longer than wide as 1½-2:1; plants 2.5-4 cm. high, glaucous green; capsule sharply 4-angled, 1¼-1½:1 .....*P. piliferum*
6. Stems usually covered for greater portion of length with dirty-white tomentum; plants 6-20 cm. high, rigid, almost terete when dry; leaves closely appressed; capsule sharply 4-angled, more or less cubical as 1¼:1, 2-3 mm. long..*P. strictum*
   Stems without dense covering of tomentum; plants 2-10 cm. high, glaucous green; leaves spreading when moist, erect when dry; capsule sharply 4-angled, 1½-1¾:1, 3-5 mm. long.....*P. juniperinum*

P. commune L. (Figs. 22-24.) Jasper, *Jefferson, Johnson, Lagrange, Martin, *Monroe, Putnam, Spencer, Starke, and Steuben counties.

P. commune L., var. **perigoniale** (Michx.) B. & S.* (Figs. 25-27.) Jasper, Lawrence, Monroe, Porter, Starke, and White counties.

P. commune L., var. **uliginosum** Hueb.* (Figs. 28-31.) Carroll, Elkhart, Jasper, Marshall, and Starke counties.

P. juniperinum Willd.* (Figs. 32-37.) Carroll, Jasper, Lagrange, Laporte, St. Joseph, Steuben, and Washington counties.

Figs. 22-52. Figs. 22-24. *Polytrichum commune* (From Frye, Polytrichaceae W. N. Am., fig. 23). Fig. 22. Dry plant, x 0.37. Fig. 23. Cross section of a few lamellae, showing their height and depth of notch in apical cells, x 93.5. Fig. 24. Capsule, x 1.9. Figs. 25-27. *Polytrichum commune*, var. *perigoniale* (From Frye, Polytrichaceae W. N. Am., fig. 23). Fig. 25. Dry Plant, x 0.37. Fig. 26. Cross section of a few lamellae, showing their height and depth of notch in apical cells, x 93.5. Fig. 27. Capsule, x 1.9. Figs. 28-31. *Polytrichum commune*, var. *uliginosum* (From Frye, Polytrichaceae W. N. Am., fig. 23). Fig. 28. Dry plant, x 0.37. Fig. 29. Tip of plant, showing perichaetial leaves and capsule, x 0.37. Fig. 30. Cross section of a few lamellae, showing their height and depth of notch in apical cells, x 93.5. Fig. 31. Capsule, x 1.9. Figs. 32-37. *Polytrichum juniperinum* (From Frye, Polytrichaceae W. N. Am., Fig. 27.) Fig. 32. Leaf, showing incurved margin and lamellae on upper surface, x 6.9. Fig. 33. Leaf tip, x 30. Fig. 34. Cross section of a few lamellae, showing smooth, flask-shaped apical cells, x 115. Fig. 35. Dry plant with capsule, x 0.46. Fig. 36. Calyptra covering immature capsule, x 2.3. Fig. 37. Capsule, x 2.3. Figs. 38-41. *Polytrichum ohioense* (From Frye, Polytrichaceae W. N. Am., fig. 20). Fig. 38. Moist plant with capsule, x 0.38. Fig. 39. Leaf, showing lamellae on upper surface, x 5.7. Fig. 40. Cross section of a few lamellae, showing common form of apical cells, x 95. Fig. 41. Capsule, x 1.9. Figs. 42-46. *Polytrichum piliferum* (From Frye, Polytrichaceae W. N. Am., fig. 30). Fig. 42. Moist plant with capsule, x 0.46. Fig. 43. Leaf, showing involute margin and lamellae on upper surface, x 6.8. Fig. 44. Leaf tip, x 30. Fig. 45. Cross section of a few lamellae, showing flask-shaped, somewhat thickened apical cells, x 115. Fig. 46. Capsule, x 2.3. Figs. 47-51. *Polytrichum strictum* (From Frye, Polytrichaceae W. N. Am., fig. 28). Fig. 47. Moist plant with capsule, x 0.38. Fig. 48. Leaf, showing incurved margin and lamellae on upper surface, x 5.6. Fig. 49. Leaf tip, x 24. Fig. 50. Cross section of a few lamellae, showing flask-shaped apical cells, x 93. Fig. 51. Capsule, x 1.9. Fig. 52. *Buxbaumia aphylla* (From Grout, M. H. M., fig. 19). Mature plant, x 2.6.

P. ohioense R. & C. (Figs. 38-41.) Allen, Carroll, Clark, DeKalb, Delaware, Elkhart, *Hamilton, Hancock, Jackson, Jefferson, Kosciusko, Lagrange, Laporte, Lawrence, Marshall, Martin, *Monroe, Montgomery, Noble, Orange, Owen, Parke, Porter, Putnam, Ripley, Steuben, *Wayne, Wells, and White counties.

P. piliferum Schreb. (Figs. 42-46.) *Monroe and Porter counties.

P. strictum Banks.* (Figs. 47, 48.) Steuben county.

BUXBAUMIACEAE

Buxbaumia aphylla L. Plants very small, rarely recognized unless in fruit; seta stout, about 1 cm. high; capsule oblique to almost horizontal, about 5-7 mm. long, upper surface flattened. Monroe, Porter, and *Putnam counties.

WEBERACEAE

Webera sessilis (Schmid.) Lindb. (Fig. 8.) Plants small, producing a general appearance of a grain of wheat (capsule) sitting in a tuft of bristles (perichaetial leaves). Brown, Floyd, Monroe, Parke, and Putnam counties.

FISSIDENTACEAE

Leaves in one plane, in two opposite rows, vertically placed, with bases appearing split along the upper edge, clasping the stem.

1. Stems radiculose-bulbiform at base; peristome none.....*Bryoxiphium*
   Stems not radiculose-bulbiform at base; peristome teeth cleft.....*Fissidens*

Bryoxiphium norvegicum (Brid.) Mitt. (Fig. 9.) Pendent upon shaded vertical faces of sandstone cliffs. Laporte, Parke, Porter, and Putnam counties.

Fissidens

1. Plants aquatic, floating, slender, flaccid; stems fasciculately branching; leaves distant, spreading, bases clasping the stem; peristome teeth 16, short, irregularly cleft .....*F. Julianus*
   Plants terrestrial, or, if submerged, not floating; stems simple or branching, not fasciculate; leaf bases clasping the stem and the lower edges of adjacent leaves above; peristome teeth 16, regularly cleft.....2
2. Leaves bordered (marginal cells unlike other leaf cells).....3
   Leaves not bordered, outermost row of cells sometimes slightly lighter in color.....8
3. Leaves, at least the sheathing base, bordered by one or more rows of linear cells....4
   Leaves bordered, sometimes more or less obscurely, by several rows of paler thick-walled cells similar in size and shape to other leaf cells.....7
4. Leaf border strong, reaching apex, usually confluent at apex with the percurrent costa; leaves oblong-lingulate, usually abruptly short-acuminate; plants 5-25 mm. high; seta terminal, 4-9 mm. long; capsule typically erect and symmetric, sometimes inclined.....*F. bryoides*
   Leaf border narrow, not strong, not confluent with costa at apex; leaves oblong-lanceolate, apices obtuse-apiculate to acute; plants 0.8-6 mm. high.....5
5. Leaves usually bordered only on the sheath; plants 1-2 mm. high; leaves 3-6 pairs, uppermost ascending to erect, up to 1 mm. in length, narrowly oblong-lanceolate; apices acute to rounded-obtuse; seta terminal; capsule erect and symmetric or slightly inclined.....*F. exiguus*
   Leaves bordered on blade as well as sheath; plants 0.8-6.0 mm. high; leaves usually 3-7 pairs, uppermost incurved-erect, up to 2.5 mm. in length.....6

6. Leaf border narrow, extending almost to the apex; leaves broadly oblong-lanceolate; apices obtuse-apiculate; plants 2-6 mm. high; seta terminal; capsules curved and cernuous.....*F. bryoides*, var. *incurvus*
Leaf border narrow, usually ending some distance below the apex; leaves narrowly oblong-lanceolate; apices acute, often apiculate; plants 0.8-5.0 mm. high, often less than 3 mm.; seta terminal; capsules erect or inclined.....*F. minutulus*

7. Leaf cells distinct, approximately 12-16μ x 15-25μ; border often indistinct; seta lateral, 1-2.5 cm. in length.....*F. adiantoides*
Leaf cells rather indistinct, approximately 6-10μ x 6-14μ border very distinct; seta lateral, up to 1 cm. in length.....*F. cristatus*

8. Costa excurrent into a short mucro; leaves finely and evenly crenulate above; seta lateral, 8-15 mm. long.....*F. taxifolius*
Costa ending in the apex or below.....9

9. Costa ending considerably below the apex; leaves minutely and irregularly serrulate above, more or less obtuse but apiculate with a pointed cell; leaf cells more or less rounded, approximately 8-11μ; seta lateral, 3-5 mm. long...*F. subbasilaris*
Costa ending shortly below the apex.....10

10. Leaf margins entire; apices rounded-obtuse; seta terminal, 1.5-3.0 mm. long; capsule erect and symmetric.....*F. obtusifolius*
Leaf margins finely and evenly crenulate above; apices rounded-obtuse and often apiculate; seta terminal, 5-10 mm. long, capsule erect and symmetric.....*F. osmundoides*

F. adiantoides Hedw. (Figs. 10-12.) Henry, *Jefferson, Laporte, Porter, Putnam, Steuben, and *Wayne counties.

F. bryoides Hedw. (Fig. 13.) *Monroe county.

F. bryoides Hedw., var. **incurvus** (Starke) Monkem. (Fig. 14.) Jasper, Parke, and Putnam counties.

F. cristatus Wils. Clark, Delaware, *Jefferson, Lake, Madison, Monroe, Porter, Tippecanoe, Washington, and Wayne counties.

F. exiguus Sull. Monroe county.

F. Julianus (Mont.) Schimp. (Figs. 15, 16.) *Monroe and Putnam counties.

F. minutulus Sull. (Fig. 17.) Jasper, Madison, Monroe, Parke, Putnam, and Warren counties.

F. obtusifolius Wils. (Fig. 18.) Jasper, *Putnam, and Owen counties.

F. osmundoides Hedw.* (Fig. 19.) Delaware, Jasper, Laporte, Madison, Parke, Porter, and Steuben counties.

F. subbasilaris Hedw. (Fig. 20.) Delaware, Henry, *Jefferson, Lawrence, Madison, Parke, Putnam, Washington, and *Wayne counties.

F. taxifolius Hedw. (Fig. 21.) Carroll, Delaware, Floyd, Lawrence, Madison, Monroe, Parke, Putnam, Washington, *Wayne, and Whitley counties.

Notes on Indiana Grasses, 1936

J. E. Potzger, Butler University

This is the fifth contribution of a series of annual reports on Indiana grasses previously unreported for the counties specified. The nomenclature is that of Hitchcock's Manual of the Grasses of the United States, 1935. In the future no locality descriptions will be given, but each county record will carry the author's collection number.

Species prefixed with a star were collected by Dr. Ray C. Friesner and carry his collection number. Two stars credit the collection to Mr. Wm. Dailey, of Indianapolis. Thanks is again expressed to Mr. Chas. C. Deam for checking the species reported in this paper. A specimen of each grass reported was deposited in the Butler University herbarium.

Agrostis hiemalis (Walter) B. S. P., Jennings, 6908. *Agrostis perennans* (Walter) Tuckerman, Clark, *9475, Jackson, *9469. *Andropogon scoparius* Michaux, Pulaski, *9426. *Andropogon virginicus* L., Henry, *9244. *Aristida intermedia* Scribner and Ball, Carroll, **7418. *Aristida longespica* Poiret, Marion, *9510, Clark, *9481, Scott, *9470. *Aristida oligantha* Michaux, Jackson, *9459. *Aristida ramosissima* Engelman., Scott, *9471. *Bromus incanus* (Shear) Hitchcock, Kosciusko, 6346. *Bromus purgans* L., Grant, 6981. *Bromus secalinus* L., Cass, 6968, Jennings, 6907. *Bromus tectorum* L., Howard, 6955, Morgan, *9584. *Cenchrus pauciflorus* Bentham, Clay, 4490, Pulaski *9441. *Dactylis glomerata* L., Howard, 6953. *Danthonia spicata* (L.) Beauvois, Jennings, 6941, Grant, 6986, Parke *5992. *Digitaria Ischaemum* Schreber, Jennings, 7394, Jefferson, *9495. *Digitaria sanguinalis* (L.) Scopoli, Grant, 7014. *Echinochola crusgalli* var. *frumentacea* (Roxb.) Wight, Morgan, 7043. *Elymus villosus* Muhl., Grant, 7021. *Elymus virginicus* var. *glabriflorus* (Vasey) Bush, Grant, 4464. *Eragrostis cilianensis* (Allioni) Link, Jennings, 7403. *E. Frankii* Steudel, Jennings, 7405. *E. pectinacea* (Michaux) Nees, Jennings, 7402. *E. spectabilis* (Pursh) Steudel, Carroll, **7417, Marion *9509. *Festuca elatior* L., Grant, 7013. *Glyceria plicata* L., Grant, *7020. *Glyceria striata* (Lamarck) Hitchcock, Grant, 7006. *Hordeum jubatum* L., Howard, 6952, Grant, 7005. *Hystrix patula* Moench, Grant, 6980. *Hystrix patula* var. *Bigeloviana* Fernald, Morgan, 7042, Monroe, 7034 a, Marion, *9958, Miami, 7097. *Melica nitens* Nuttall, Cass, 6965. *Muhlenbergia mexicana* (L.) Trinius, Clay, 4490. *Muhlenbergia sylvatica* Torr., Brown, 6675, Clark, *9486. *Panicum Boscii* Poiret, Knox, 4397. *Panicum Boscii* var. *molle* Vasey H. & C., Monroe, 7036a. *Panicum clandestinum* L., Clark, *9476, Grant, 7024. *Panicum capillare* L., Carroll, **7416. *Panicum dichotomiflorum* Michaux, Jennings, 7393, Jefferson, *9505. *Panicum Gattingeri* Nash, Brown, 6680. *Panicum huachucae* Ashe, Grant, 6982. *Panicum latifolium* L., Grant, 7032. *Panicum philadelphicum* Bernardi, Bartholomew, 6684, Marion, 4881. *Paspalum pubescens* Muhlenberg, Carroll, **7415, Jennings 7400. *Paspalum pubiflorum* var. *glabrum* Vasey, Jennings, 7406. *Phalaris arundinacea* L., Jennings, 6905. *Phleum pratense* L., Jennings, 6930, Grant, 6990. *Poa annua* L., Grant, 6772. *Poa compressa* L.,

Grant, 6983, Jennings, 6923. *Poa pratensis* L., Howard, 6954, Grant 6813. *Poa trivialis* L., Grant, 7026. *Poa Wolfii* Scribner, Grant *9795. *Setaria viridis* (L.) Beauvois, Grant, 7011. *Sphenopholis intermedia* (Rydb.) Rydb., Grant, 7008. *Sporobolus asper* (Michaux) Kunth, Hamilton, 6539.

Observations on the Methods of Stipe-formation in Stemonitis and Comatricha

WILLIAM D. GRAY, University of Pennsylvania

During the course of the writer's observations on myxomycete plasmodia, it has become apparent that many generic as well as specific behavior differences are to be expected. By behavior is meant the various conformations and color changes that are passed through in the development of sporangia from plasmodia; the time required to complete fructification is also taken into account, although it is less likely to be a fixed character. Myxomycete fructifications[1] are of three types: aethalioid, plasmodiocarpous, and sporangiate; the last may be either sessile or stiped. Naturally the behavior of the plasmodium of a plasmodiocarpous species would differ from that of either a sporangiate or an aethalioid type. In addition to such differences, however, there occur differences between forms which possess the same general type of fructification; this is shown particularly well by members of the genera Stemonitis and Comatricha.

Stemonitis and Comatricha are closely-allied genera belonging to the family Stemonitaceae, and mature forms of members of the two genera, when examined macroscopically, show many resemblances—so many, in fact, that at one time the representatives of both genera were included in the same genus. Plasmodia of Stemonitis and Comatricha characteristically inhabit the interior of rotten wood, emerging only for fruiting; in the majority of known cases, the typical plasmodial color is white. A general feature in sporangia of both genera is the presence of a long central columella, which is simply an elongation of the stipe. Observations on species of both genera show that the process by which the stipe and columella are developed in Stemonitis differs somewhat from that process in Comatricha. It is hardly to be expected that stipe- and columella-formation of all the species of Comatricha would be uniform; this is also to be said for species of Stemonitis, since there are forms which may be considered more or less border-line species between the two genera.

A review of the literature yields but few references to the subject of stipe- and columella-formation. DeBary (1884) presented some observations concerning this process in *Stemonitis axifera* (Bull.) Macbr. (*S. ferruginea* of Ehrenberg), but his method of viewing the fruiting bodies was to harden them with alcohol and then render the protoplasm transparent with glycerine. By this method, according to deBary's figures (Figs. 2a and 2b), it may be shown that formation of the stipe and columella begins at an early stage in the development of the fruiting body. Bisby (1914), working on the development of the capillitium

[1]Macbride and Martin (1934) define these as follows: *aethalium:* a fructification in which all or a considerable part of a given plasmodium is involved and in which differentiation has not proceeded to the delimination of separate sporangia; *plasmodiocarp:* a fructification which has the interior structure of a sporangium, but which retains the netted form and outline of the plasmodium; this type is formed by the aggregation of protoplasm into a few of the larger veins of the plasmodium as it rests upon the surface of the substratum; *sporangium:* typically an erect fructification of definite form and structure for a given species, each sporangium representing only a small part of the protoplasm of a given plasmodium.

in *Stemonitis fusca* Roth, included some material on the formation of the columella; his investigations, however, were largely cytological. Details of the development of *S. fusca*, from plasmodium to sporangia, were described by the writer (Gray, 1936); in this description no figures of the developing sporangia were presented. Jahn (1931) gave an account, accompanied by excellent photographs, of various stages in the development of *Comatricha nigra* (Pers.) Schroet.; he had previously published (1899) on this same species, incorrectly designated *C. obtusata* Preuss.

Were it possible to grow members of this family at will, the matter of observing the development of all species would be simplified; at present, however, one must rely upon finding plasmodia in their native haunts, removing them to the laboratory, and there observing them during the fruiting process. It has been the experience of the writer ordinarily to find emerging plasmodia of these two genera in the afternoon or evening; this is by no means, however, a set rule. The following summaries and the accompanying diagrams will serve, in a measure, to point out the main features of the stipe-forming and other developmental processes observed in the two genera. Figs. 1, 2, and 3 (with the exception of 2a and 2b) are diagrams of species observed by the writer; Figure 4 is redrawn from photographs by Jahn.

Stemonitis fusca Roth. (Fig. 1, *a-e*) Plasmodium pearly-white, relatively large.

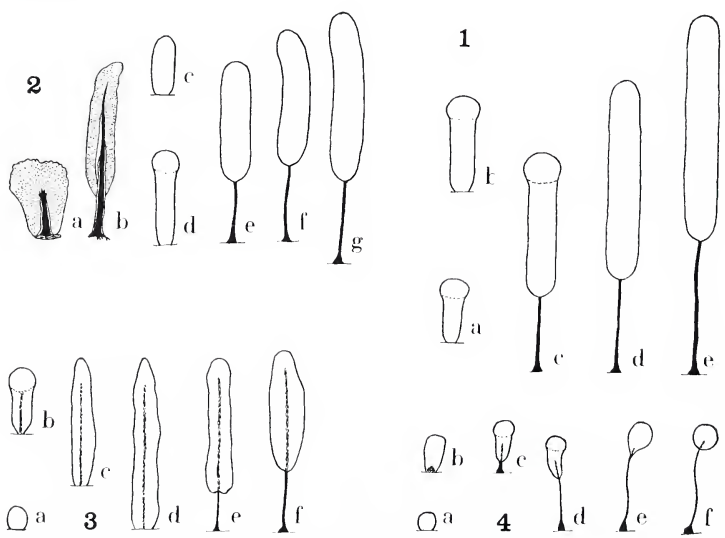

Fig. 1. *Stemonitis fusca* Roth, showing a sporangium in the various stages of development; *a*, 17½ hrs. after emergence; *b*, 19½ hrs.; *c*, 21½ hrs.; *d*, 26½ hrs.; *e*, 36½ hrs. Fig. 2. *Stemonitis axifera* (Bull.) Macbr. *a* and *b* (redrawn from deBary), longitudinal sections of young sporangia; *c-g*, a sporangium in the various stages of development; *c*, 3¼ hrs. after emergence; *d*, 8 hrs.; *e*, 12 hrs.; *f*, 17 hrs; *g*, 19 hrs. Fig. 3. *Comatricha typhoides* (Bull.) Rost. *a*, sporangium 8 hrs. after emergence; *b*, 10 hrs.; *c*, 11 hrs.; *d*, 13¼ hrs.; *e*, 13¾ hrs.; *f*, 14½ hrs. Fig. 4. *Comatricha nigra* (Pers.) Schroet. (redrawn from Jahn's photographs); *a*, sporangium shortly after emergence, the times listed for the following figures representing hours advanced past the stage shown in Fig. 4a; *b*, 2 hrs., 47 min.; *c*, 4 hrs., 43 min.; *d*, 7 hrs., 22 min.; *e*, 8 hrs., 55 min.; *f*, 9 hrs., 38 min. Magnification x4, except 2*a* and 2*b*, which are x6 and x7½, respectively.

Since the sporangia of this species occur in large clusters, the developing sporangia are intimately associated. Figure 1, a represents a single sporangium 17½ hours after the emergence of the plasmodium; at this point, the sporangium consists solely of a white, protoplasmic column, tipped with a bulbous enlargement. Figure 1, *b* is essentially the same as Figure 1, *a*, being a slightly more advanced stage. Figures 1, *c*, 1, *d*, and 1, *e* represent still further advanced stages in which the development of the stipe may be seen. The approximate time for completion of the fructification was 89 hours.

Stemonitis axifera (Bull.) Macbr. (Fig. 2, *a-g.*) Plasmodium pearly-white, developing into closely-associated sporangia as in *S. fusca.*

On the whole, plasmodia of this species are inclined to be more active upon emergence than are plasmodia of *S. fusca.* As may be seen from the diagrams (Fig. 2, *c-g*), development in the two species follows the same general lines, and, at certain stages, the species cannot be determined with certainty; however, there is a time variance, *S. axifera* requiring only 19 hours as compared to 89 hours required by *S. fusca.*[1] The two species pass through approximately the same color changes, white, pink, lavender, and finally brown, although the final shade of brown differs between the two species.

It is to be noted that in neither species of Stemonitis is there any external evidence of the existence of a columella. The sporangia are formed first, then the stipes are developed, appearing simply to lift the sporangia up from the substratum. Of course, the stipe is formed within the protoplasmic column, but obviously does not assume its final form and shining black color until it is exposed. Apparently this change in color takes place as the stipe is exposed. DeBary (1884) has shown that the formation of the stipe and columella begins in the very early stages in the development of *S. axifera;* this is not apparent to the observer, however, unless the immature sporangia are fixed and sectioned. Figures 2, *a* and 2, *b* are redrawn from deBary's figures of longitudinal sections of young sporangia of *S. axifera.*

Comatricha typhoides (Bull.) Rost. (Fig. 3, *a-f.*) Plasmodium white, but appearing somewhat finely granular and not of the same shining, pearly quality of whiteness exhibited by the two preceding species; rather active and inclined to divide into several smaller plasmodia, from some of which only one sporangium is developed; sporangia not closely aggregated.

Figure 3, a represents a sporangium in the very early stages (eight hours after the emergence of the plasmodium). Figure 3, *b* is the same sporangium two hours later; it is to be noted that a bulbous enlargement such as is shown by both species of Stemonitis is evident. The development of the stipe and columella has begun; they are dark in color, and their outlines show through the white protoplasmic mass. In Figure 3, *c* (11 hours after emergence), the protoplasmic column has elongated; dark stipe and columella are quite evident. This protoplasmic column continues to elongate until it has reached the maximum height of the fructification (Fig. 3, *d*), then the protoplasm contracts

[1]Further observations may show that the exact time requirements vary within a species.

upward along the central axis and thus exposes the already apparent stipe at the base of the fructification. Color changes are as follows: white, pale lavender, dark lavender, brownish-purple, and finally dark brown.

Comatricha nigra (Pers.) Schroet. (Fig. 4, *a-f.*) No observations on this species were made by the writer; diagrams drawn from Jahn's photographs have been introduced for the purpose of comparison. Figure 4, *a* represents a sporangium shortly after emergence, and Figure 4, *b*, the same sporangium two hours and forty-seven minutes later. At this stage may be seen the darkened central portion near the base, which marks the beginning of the formation of stipe and columella. Figure 4, *c* shows this sporangium about four hours and 43 minutes after emergence; the dark central portion, representing stipe and columella, has elongated; a portion of the stipe is already exposed. The stipe continues to elongate, and eventually the cylindrical protoplasmic column contracts along the stipe to form a more or less spherical sporangium about nine hours and 38 minutes after emergence (Fig. 4, *f*).

TABLE I. DEVELOPMENTAL FEATURES

SPECIES	Approximate Time Required	Color Changes in Order	Final Shape
S. fusca	89 hrs.	pearly-white pink pale lavender dark brown dark chocolate brown	cylindrical
S. axifera	19 hrs.	pearly-white pink pale lavender dark brown wood brown	cylindrical
C. typhoides	23 hrs.	granular white pale lavender dark lavender purple dark brown	cylindrical
C. nigra	?	watery white ? ? ferruginous or dark brown	spherical or oval

C. nigra differs from *C. typhoides* in that the stipe of the former continues to elongate after the basal portion is exposed. The early and obvious development of the stipe and columella is common to both species of Comatricha as is the contraction of the protoplasmic column along the central axis. On the contrary, at no time in the development of the two species of Stemonitis is the columella apparent. Known developmental features of the four species under discussion are summarized in Table I.

Acknowledgment

The author is indebted to Dr. K. D. Doak, Allegheny Forest Experiment Station, for helpful criticisms in the preparation of the manuscript.

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Fungus Growth as Affected by Varying Concentrations of Salts

R. B. Zumstein, Purdue University

Potato dextrose agar is a suitable medium for growing most fungi. The potato dextrose agar manufactured by the Digestive Ferments Company is more convenient to use and the results appear to agree with a comparable medium made up by the laborious process suggested by the formula for the making of potato dextrose agar. Digestive Ferments' P.D.A. was therefore used in this investigation.

My purpose was to determine whether the addition of mineral salts commonly believed to be of nutritional value would increase the effectiveness of P.D.A. as measured by colony diameter.

Technique

Phytophthora cactorum was selected as the test fungus. The salts added were potassium nitrate, potassium chloride, sodium nitrate, and sodium chloride, giving a variation of both cation and anion. Molar concentrations of 0.01, 0.1, 0.2, 0.4, 0.6 and 0.8 were used. Twenty grams of Difco P.D.A. were added to 500 cc. of each of the above molar concentrations of the four salts. The media were prepared in the usual manner, tubed, and sterilized in the autoclave at 15 pounds for 20 minutes. Petri plates containing the various media were then inoculated with 5 mm. disks of a pure culture of *P. cactorum*. Light was excluded from the plates except when measuring colony growth and recording results. Measurements were taken every 12 hours. The results are shown in Figures 1-5.

Summary and Conclusions

1. Difco potato dextrose agar is made more effective by the addition of mineral salts usually considered of nutritive value.

2. The effectiveness of each mineral salt is limited by the molar concentration.

3. During 192 hours of development, the 0.1 M concentration of sodium chloride and potassium chloride stimulated greater growth than 0.2 M concentration of these salts, with potassium chloride showing the greatest stimulation.

4. In the case of sodium and potassium nitrate, the 0.2 M concentration stimulated greater growth than the 0.1 M concentration of these salts, with sodium nitrate showing the greatest stimulation.

5. All of the media with 0.1 M and 0.2 M concentrations of salts gave better growth than did the control of Difco potato dextrose agar alone.

6. Molar concentrations of 0.6 and above caused a decreased growth, the growth decreasing with the increase in concentration.

7. Total average growth for each salt indicates that potassium chloride gave most growth for the average of the six concentrations.

8. The 0.2 M concentration gave the greatest average growth for the four salts used, with the 0.1 M concentration showing only 0.05 mm. less growth.

9. Of the six molar concentrations used, 0.1, 0.2, and 0.4 indicated a greater average growth with the four salts than did the control of Difco potato dextrose agar.

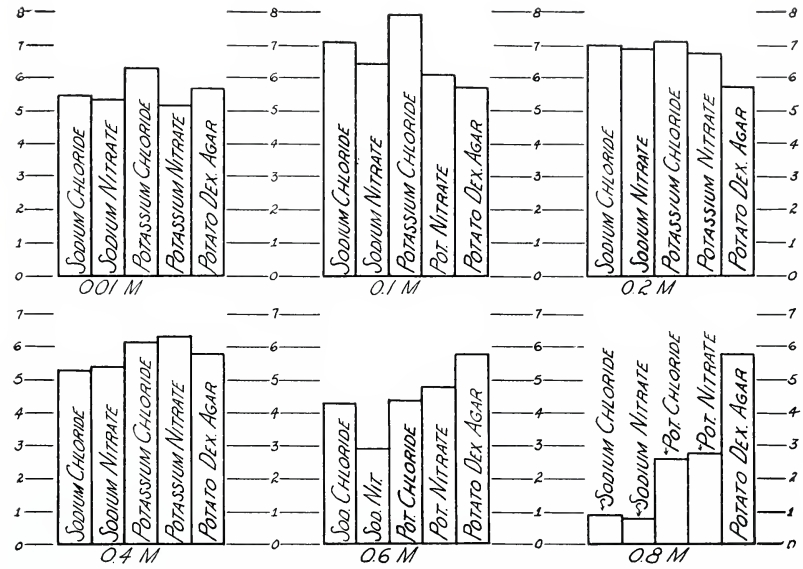


Fig. 1. Growth of *Phytophthora cactorum* for 192 hours on varying molar concentrations.

Some Physical Features Associated with Pliability of Wood

J. E. Potzger and Florence Geisler, Butler University

Many books and papers have been written on mechanical properties of wood, and elaborate equipment in testing laboratories, where accurate mathematical calculations are made of physical and mechanical properties of wood, speak of extensive investigations of this factor because of great economic importance of such knowledge. Wood plays a major part in civilized life as material used for all sorts of implements, furniture, building, and construction work, where mechanical properties determine the fitness of a specific wood for a particular use.

The present investigation was not prompted by any economic motive but simply by the scientific curiosity as to whether or not pliability of wood was entirely a feature associated with the chemical nature of the walls of the fibers, or whether it was also linked to external physical features of the fiber, i.e., thickness of wall, arrangement of fibers within the xylem, length of fiber, etc.

Procedure

The terms *stiffness* and *flexibility* used by wood technologists come nearest defining the meaning of pliability as used in the present paper. Garratt (3) defines these terms thus: "Stiffness is the property by means of which a body acted upon by external forces tends to retain its natural size and shape, or resists deformation. Thus a material that is difficult to bend or otherwise to deform is stiff. In contrast to this, a material that has the capacity to bend a great deal without breaking is said to be flexible. Flexibility is not the exact counterpart of stiffness, however, as it also involves toughness and pliability."

Four woody species were examined, viz., *Dirca palustris* L., *Salix nigra* Marsh, *Fagus grandifolia* Ehrh., and *Carpinus caroliniana*, Walt.

On empirical observation one could readily classify the species as representatives of three degrees of pliability. The marked difference in this respect promised a marked difference in physical characteristics causing such property.

The stems examined were approximately of the same age, i.e., nine to eleven years old. In cross section, thickness of cell wall and width of lumina in the fiber cells were measured. Since measurement from edge of lumen to middle lamella was difficult to make, measurement was made from lumen to lumen, involving, thus, always a measurement of a double wall. One hundred measurements were made in each instance, being divided between areas near the pith, half way between pith and cambium, and near the cambium. Fibers measured were approximately equally divided between spring and summer wood.

In tangential section, measurements were made of length and width of fibers, and number of cells constituting the xylem rays were counted. Observations were also made on uniformity of cell arrangement, grouping of fibers, and characteristics of the xylem rays.

Discussion

The study indicates in general that pliability of wood is associated with marked external physical features of the fibers, i.e., length of fiber and thickness of wall and lumen. Dirca has the thinnest walls, and the largest lumina of the four species examined. It is also the most pliable of these woods. Fagus as the other extreme, has the thickest fiber walls and smallest lumina. Salix and Carpinus are intermediate between these two as to thickness of cell wall, but Salix has wider lumina than Carpinus (Table I).

There is little difference between Fagus and Carpinus in the total thickness of the fibers, but Fagus has 100% more wall in a unit area than Carpinus. Comparing percentage of wall and total thickness of fiber, we again have a progressive increase in wall thickness from Dirca to Fagus, viz. Dirca 18%, Salix 30%, Carpinus 32%, and Fagus 64% (Table I).

TABLE I. MEASUREMENT AND COMPARISONS OF WOOD FIBERS FROM CROSS SECTIONS. MEASUREMENTS IN MICRONS

Species	Thickness of Wall	Width of Lumen	Total Thickness of Fiber	Percentage Wall of Total Thickness
Dirca palustris	2.949	13.345	16.294	18
Salix nigra	3.791	8.908	12.699	30
Carpinus caroliniana	3.349	7.22	10.569	32
Fagus grandifolia	6.409	3.646	10.055	64

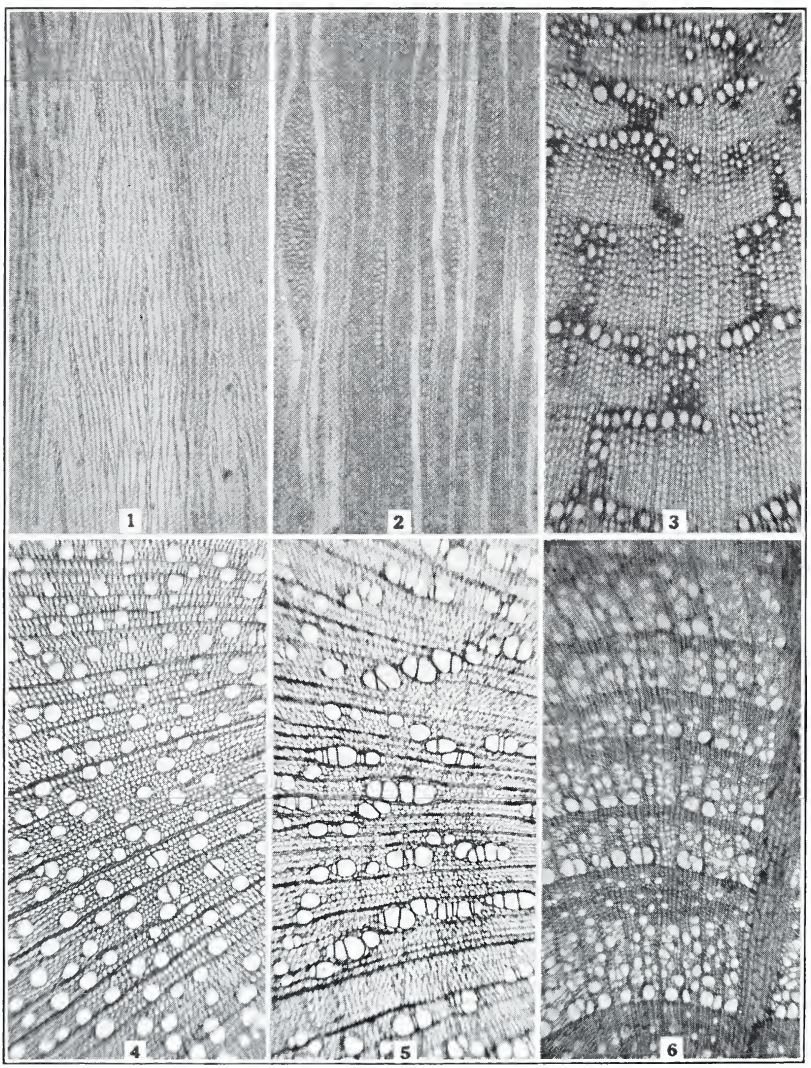
We realize that thickness of wall *per se* would not necessarily mean greater rigidity in a stem, for the chemical nature of the cell wall could easily be the determining factor in rigidity. This was shown by Dadswell and Hawley (I) who found a slightly higher lignin content and slightly lower cellulose content in wood from brash oak than in tough wood from the same species. However, the uniform increase in thickness of fiber wall associated with progressively greater rigidity of stem would, seemingly, justify the conclusion that thickness of fiber wall is one of the prime factors associated with rigidity of wood.

Length of fiber correlated with pliability in wood was the opposite of what was anticipated, for the most pliable wood had the shortest fibers (Table II). However, there was a progressive increase in length from the most pliable to the most rigid wood: Dirca 161.11μ, Salix 353.36μ, Fagus 454.49μ, Carpinus 494.88μ. Probably the shorter fibers may permit a more ready bending, while the long, thick-walled fibers of Fagus and Carpinus may add rigidity to the whole stem.

The xylem rays of Dirca are usually uniseriate or biseriate (Fig. 1); Salix has mostly uniseriate rays, Carpinus has uniseriate or biseriate

rays, but they are more numerous than in either Dirca or Salix; Fagus has bulky rays, up to eight cells in width (Fig. 2). Some of these rays are divided by fibers which would make them a sort of aggregate ray. One could also classify them as compound rays or very large multiseriate rays frequently found in oaks, as described by Eames and McDaniels (2, p. 177).

The pattern of the vessels is strikingly different in the four woods.



Figs. 1-6. Fig. 1. Tangential section of wood of Dirca. Fig. 2. Same of Fagus. Fig. 3. Transverse section of wood of Dirca. Fig. 4. Salix. Fig. 5. Carpinus. Fig. 6. Fagus.

Table II. Length of Wood Fiber and Width of Xylem Rays in Tangential Section. Measurements in Microns

Species	Length of Fiber	Width of Xylem Ray
Dirca palustris	161.11	237.35
Salix nigra	353.365	275.57
Carpinus caroliniana	494.886	270.93
Fagus grandifolia	454.498	451.87

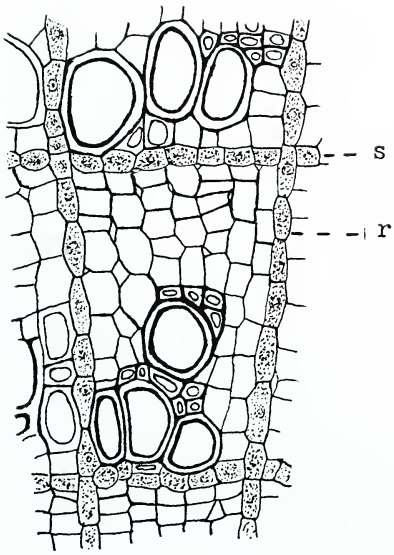


Fig. 7. Transverse section of wood of Dirca, showing storage tissue, *s*, and xylem ray, *r*.

Dirca has characteristically five to nine in a group, forming a sort of network throughout the xylem (Fig. 3.) In Salix the vessels are fairly evenly distributed and are very uniform in size (Fig. 4), while in Carpinus they are erratically grouped and arranged (Fig. 5). Fagus has most vessels per unit area, and all are arranged in definite rows (Fig. 6). Neither grouping of vessels nor nature of the xylem rays seems to have any bearing on the rigidity of the stem; the structure of the fibers as previously described apparently controls this characteristic of the wood.

A unique feature in Dirca is a special storage tissue one cell in width on the inside of every annual ring. The cells resemble those of the xylem rays both in shape and content (Fig. 7).

Summary

1. Some physical characteristics of fibers in the xylem of *Dirca palustris*, *Salix nigra*, *Carpinus caroliniana*, and *Fagus grandifolia* are considered as to cause of degrees of pliability in wood.

2. Pliability is apparently associated with striking differences in physical features of the wood-fibers.

3. The walls of the fibers become progressively thicker from the most pliable to the most rigid wood.

4. Width of lumina becomes smaller from the most pliable to the most rigid wood, being four times as wide in Dirca as in Fagus.

5. Length of fiber increases with increasing rigidness of wood, being almost three times as long in Fagus as in Dirca.

6. Xylem rays are characteristically uniseriate or biseriate in Dirca, Salix, and Carpinus, while in Fagus they are of the multiseriate, aggregate or compound type.

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Soil Acidity and Hemlock Reproduction In Relic Colonies In Indiana

J. E. Potzger and R. C. Friesner, Butler University

A voluminous literature on pH of soil and its relation to seedling growth and establishment is evidence of the importance ascribed to this factor by ecologists and foresters. It is also well known that cryptogams (2) and many herbaceous phanerogams (11) are limited to a definite optimum range of acidity. While trees as a whole may probably be less sensitive to an optimum range than herbs, they too, especially in the seedling stage, frequently show a marked preference for certain ranges in pH, showing less sensitiveness to deviation from the optimum towards greater acidity than towards alkalinity (8).

The present paper was not prompted by any immediate practical importance which its results might have, but is a phase of the extensive investigations the authors carried on in relic colonies of hemlock *(Tsuga canadensis)* at Trevlac, Brown County, and Pine Hills, Montgomery County, Indiana.

In Indiana, hemlock occupies a unique isolated position (3), usually along rims of rocky cliffs (Fig. 1). These cliffs form a line diagonally across the state from Jefferson, Clark, Floyd, and Crawford Counties on the southeast to Parke and Montgomery Counties on the northwest. These small isolated colonies of hemlock seem to hold their own near the broad-leaved competitors but are not able to expand into broad-leaved territory. In this respect, then, hemlocks in Indiana offer many interesting problems for the ecologist. Soil moisture and evaporation studies have been carried on at both of the above stations (3, 4, 5), and it was found that hemlocks occupy habitats with less soil moisture and are subject to greater water loss by transpiration than broad-leaved forests nearby.

Seedlings are abundant at both places, but young trees are limited in number, and, as previously stated, the forest does not extend its boundary. Seedlings are usually most abundant in beds of mosses and are totally absent among the broad-leaved trees on the plateau but a short distance from the cliff. This prompted the present investigation, to see if by transects of soil samples it could be discovered whether or not there existed an important relationship between pH of soil and abundance of seedlings.

Procedure

Soil samples were taken at the surface and at six-inch and twelve-inch depths. Transect lines were run from and to areas of abundant hemlock reproduction and mature stands, intermittently through areas where seedlings were wanting, and also from hemlock groves to broad-leaved forest.

A hole over a foot in depth was dug with a trenching spade, and samples of soil were taken from the side of the hole. Samples were taken at ten to twenty-five foot intervals. The soil was collected in small paper sacks, and reading of pH was made on the Youdon hydrogen-

ion apparatus within a few days after collection. Three readings were made of each soil sample, and these three readings were averaged for the transects shown in our curves (Figs. 3, 4).

Observations

Trevlac, Brown County.—The numerous graphs from both stations tell the same story, i.e., seedling abundance is linked to a definite optimum degree of acidity of soil. In nearly every instance where the transect was from deciduous forest through hemlock groves and areas where seedlings were abundant, there is a decided fluctuation in acidity of the soil, it being most acid where hemlocks were present. This is well illustrated by Transects 1, 2, 3 for surface soil (Fig. 3). As a rule, there is more fluctuation in acidity in the surface soil than in the six- and twelve-inch soil (Transects 1, 2, 3). Apparently hemlock prefers an acidity range between 4.5 and 5.5, with an optimum of about pH 5.

Pine Hills, Montgomery County.—This is another interesting area of relics; both *Tsuga canadensis* and *Pinus Strobus* are present. Topo-

Fig. 1. White pine and hemlock along cliffs, Pine Hills, Montgomery County.

Fig. 2. Birdseye view of isolated colonies of hemlock and white pine along cliffs in Pine Hills, Montgomery County.

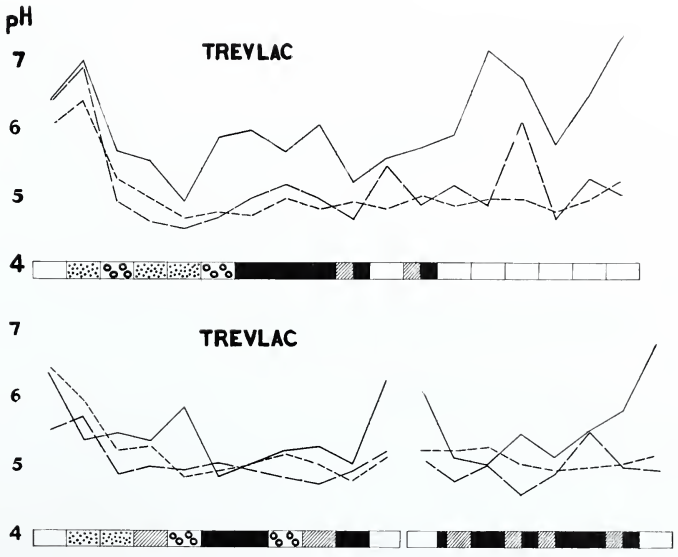

Fig. 3. Transects 1-3; soil samples from Trevlac, Brown County. Legend as in Fig. 4.

graphically the region is similar to Trevlac. It is a region of eccentric topographic features,—sudden and abrupt changes, grotesque rock formations, semi-xeric shallow soils, deeply alluviated narrow valleys, and flat narrow plateaus (9). Here, too, hemlock and pine cling closely to the edges of cliffs, at times making one wonder why their extent is so sharply delimited. Groves of evergreens seen in a panoramic view always indicate cliffs in the topography (Fig. 2).

The pH of the soil is similar to that at Trevlac (Transects 4-7, Fig. 4). Transect 7 was made on the cliffy wall known as Devil's Backbone. The open higher plateau was densely covered with *Danthonia spicata*, with no hemlock seedlings present and acidity less than in adjacent areas where seedlings were abundant or where moss covered the surface. The range of pH in this whole transect where seedlings of hemlock were present is remarkably uniform for all three depths of soil, i.e., close to 4.5. As soon as one reaches the floodplain deciduous forest where hemlock seedlings are absent, the pH rises in a sharp upward swing. Nowhere did we find hemlock or pine seedlings or young trees in the flood-

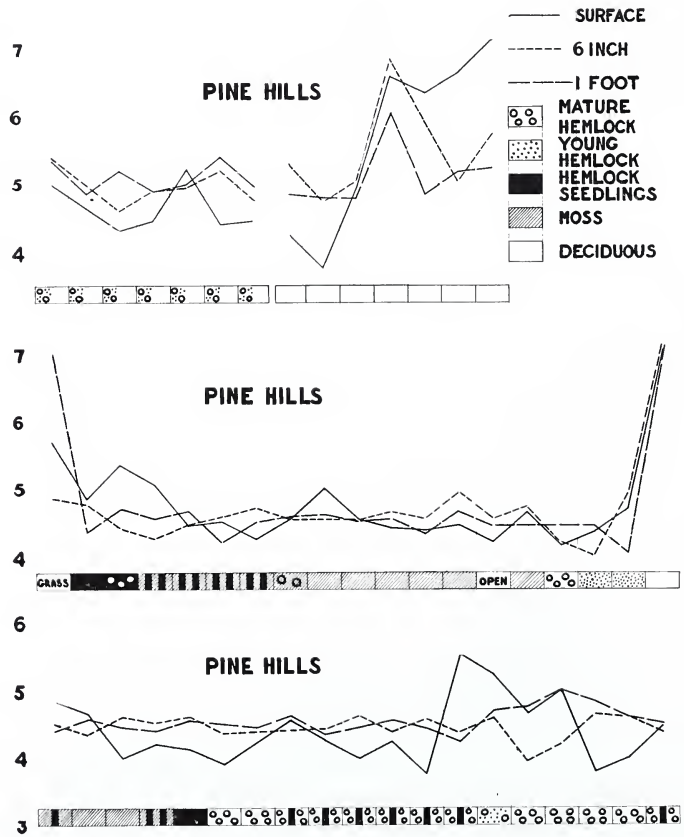

Fig. 4. Transects 4-7; soil samples from Pine Hills, Montgomery County.

plain, and seeds must fall in abundance into these areas from the steep cliffs above, where these trees overhang the cliffs (Fig. 1).

In Transect 4 we note the same tendency of range in pH, i.e., 4.5 to 5.5 where a transect passed through the densest hemlock and white pine groves on the slope and plateau north of Devil's Backbone. The six- and twelve-inch soils, are, again, marked by greater uniformity of acidity range than the surface soil.

Discussion

As one analyzes the hundreds of pH readings made on surface soil in the present study, he is impressed with the remarkable uniformity of acidity range where hemlock seedlings or mature trees are present. We realize that pH is but one of the factors exerting controlling influence, for we know from former investigations (3,5) that hemlock grow where evaporation is higher and soil moisture lower during the growing season than in adjacent areas of deciduous forest; we even suggested (3) that leaf litter may be an inhibiting factor because of its mechanical effect on seedlings, yet one cannot well ignore the prolific growth of seedlings in moss beds which are known for their acidifying influence on the soil. A glance at any of the transects where moss is indicated will show that the pH of the soil is strikingly of the same range as soil where seedlings were abundant.

Daubenmire (1), working in a similar relic colony at Turkey Run, Parke County, found conditions which parallel ours, viz., pH 4.5 to 5 where hemlock was abundant and 5.5 to 7 in deciduous forest. He also found a greater uniformity of lower acidity in the subsoil than in the surface soil. This one would expect, for surface soil is subject to greater diversity of influences which have a bearing on acidity, i.e., decomposition of leaf litter, leaching, etc. It is, however, the surface soil especially which is concerned in seed germination and seedling establishment.

Two features are obvious in the seven transects before us: first, the uniformity in pH range 4.5 to 5.5 where a transect passes through hemlock and moss-covered areas (Transects 2, 4, 5); and, secondly, the fluctuation between greater acidity in hemlock-controlled areas and less acidity in deciduous forest (Transects 2, 3, 6, 7), and this is much more significant if we consider that the two stations are separated by long distances and correlate in the same features with results from another area worked by Daubenmire (1).

The most outstanding example of fluctuation at Trevlac is the long transect shown in Transect 1. The line began in a deciduous forest halfway up a cliff and ended well up on the plateau in a sassafras-oak forest after having passed through a hemlock forest along the rim of the cliff. The reduced acidity in the six- and twelve-inch soils of the lower slopes is, no doubt, due to seepage from the cliffs which are partly of limestone makeup, while the subsoil on the plateau is probably more uniformly acid because of leaching. A tabulation of samples taken in deciduous forest, hemlock stands, and seedling beds tells the same story as the individual transects. Twenty-six samples in deciduous forest showed a range of pH 4.26 to 7.03 with a median range of 6.5;

twenty-eight samples from seedling beds showed a range of pH 3.96 to 6.14 with a median range of 5.08; twenty-six samples from mature stands of hemlock showed a range of pH 3.77 to 6.28 with a median range of 4.49.

In the Pine Hills area, Transects 5 and 6 are of considerable interest. The transect begins in the transition zone where pine, hemlock, and deciduous trees intermingle close to the canyon rim and continues well into the deciduous forest on the plateau beyond. As Transect 6 shows, there is a sudden decrease in acidity as the line crosses into the deciduous forest.

Now what does experimental evidence under controlled conditions show on the relationship between pH and seedlings of conifers?

Sundling, McIntyre, and Patrick (10) found that seedlings of conifers grew poorly in seedbed soil with a pH of 6.2 to 6.8. "In all cases the best seedlings were found in areas where the soil was most acid." Jack pine, white pine, red pine, and Norway spruce seedlings developed best in soil whose pH range was between 4 and 6. According to their Table 4, the following pH made for best general development and increase in weight: *Pinus Strobus*, 5.5; *P. resinosa*, 5.0; *Picea abies*, 4.6.

Wherry (12) found that of 23 eastern conifers more than half preferred acid soils. Kelly (6) reports that *Pinus rigida* in New Jersey is partial to soil ranging in acidity between 5.2 and 5.6, shunning more alkaline soils near the shore (his Table 2). Moore (8) working under experimental conditions found that seedlings of pitch, jack, and red pine had a decided acidity preference. We found at Pine Hills that white pine seedlings had an acidity preference similar to that of hemlock.

In which way does alkalinity influence the growth of seedlings? No doubt it has a bearing upon a number of factors dealing with normal functioning of the plant. Moore (8) found that when he added slaked lime to the soil, the roots of jack, pitch, and red pine became brown and shriveled. Sunding et al. (10) found in their series of decreasing acidity that lateral roots 0.5 to 5 cm. in length decreased in number in soil above 5.5 in *Pinus Strobus*, *P. resinosa*, *P. banksiana*, and *Picea abies*. In some cases the longer lateral roots were absent entirely. This must certainly influence absorption and reduce the extent of the root system.

Acidity also influences mycorrhiza on the roots, which in turn will affect absorption in the tree. According to Melin, quoted by Sunding et al. (10), optimum growth of mycorrhiza on pine and fir seedlings occurred at a pH 5 or a little lower. This will no doubt vary greatly, however, in different so-called ecological races of the same species, but it indicates that disturbances occur in absorption when seedlings of conifers must grow in soil lacking the optimum acidity.

For hemlock, our own field data thus reflect a similar definite optimum pH range for most efficient germination and seedling growth.

Summary

1. Comparative acidity studies were made in hemlock and deciduous forest,

2. Transect lines were run from hemlock to deciduous forest.

3. As a whole, soil where hemlock trees and seedlings grow is more acid than in deciduous forest.

4. The two stations studied yielded remarkably similar results.

5. Hemlock seedlings seem to prefer a pH 4.7 to 5.5.

6. Soil under beds of mosses has approximately the same range in pH as that where hemlock seedlings are abundant.

7. Acidity of soil is apparently one of the vital edaphic factors in hemlock reproduction in Indiana.

We acknowledge with thanks the preparation of the transect figures by Mr. Robert Prettyman.

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PROGRAM OF THE SECTION ON CHEMISTRY

Chairman: J. M. FULMER, DePauw University

1. Some reflections on organic chemical formulas. Wm. M. Blanchard, DePauw University.
2. Selenium dioxide as an oxidant. J. F. Deupree and R. E. Lyons, Indiana University.
3. Seleno-cyanation of aniline. T. H. Chao and R. E. Lyons, Indiana University.
4. The production of hydrogen selenide by heating paraffine with selenium in the presence of a catalyst. T. H. Chao and R. E. Lyons, Indiana University.
5. Conductometric titration of iron, aluminum, and magnesium. E. W. Kanning and E. H. Lewis, Indiana University.
6. Catalytic esterification with dihydroxyfluoboric acid. J. W. Kroeger, F. J. Sowa, and J. A. Nieuwland, University of Notre Dame.
7. A fractionation column employing absorbents. R. J. Hartman and D. H. Jung, Indiana University.
8. Preparation and properties of 2, 3, 4, 6 tetraethyl-alpha-ethyl-D-glucoside. Wendell H. Kinkley and Ed. F. Degering, Purdue University.
9. A lecture demonstration in organic chemistry. Ed. F. Degering, Purdue University.
10. The preparation and properties of some ethoxy-compounds. Ned Guthrie, Hanover College.
11. Experimental meningococcal infection of mice. Vernal Irons, Texas State Department of Health, Austin, Texas.

Papers No. 2, 3, 4, 5, 6, 7, and 9 were read by title. The following title of a paper published in this volume was not included in the published program:

Esterification in the presence of anhydrous salts. H. T. Briscoe, Indiana University, and F. M. Whitacre, Case School of Applied Science.

Dr. Paul D. Wilkinson, of Indiana State Teachers College, was elected chairman of the section for 1937.

Selenium Dioxide as an Oxidant

JOHN F. DEUPREE[1] with ROBERT E. LYONS, Indiana University

The investigations of Riley, Morley, and Friend[2] established the fact that selenium dioxide oxidizes a number of types of organic compounds and at times exhibits marked specificity, yielding aldehydes and ketones which are difficult to prepare by ordinary methods. Later Riley and co-workers extended the study to include olefines,[3] alcohols, esters,[4] dibenzyl, stilbene, and phenyl-substituted aliphatic esters.[5]

The reactions of selenium dioxide with compounds containing the group $-CH=CH-CH_2-$ were investigated by Schwenk and Borgwardt;[6] with ethyl acetoacetate by Müller;[7] with poly-nitrotoluenes by Fisher;[8] and with several substances containing double bonds by Postowsky and Lugowkin.[9]

The purpose of the work described in this paper has been to extend the use of selenium dioxide as an oxidizing agent and also to elaborate and verify some of the previous work in this field.

Experimental

Reaction of Propionic Acid with Selenium Dioxide. Propionic acid when boiled with selenium dioxide yields pyruvic acid and amorphous black selenium.

Mixture of 10 g. propionic acid and 2 g. selenium dioxide were maintained at boiling temperature under reflux for periods of 4 to 24 hours and subjected to distillation under reduced pressure, and the pyruvic acid was determined in aliquot portions of the distillates by the method of Wieland,[10] as described by Wendel,[11] with results as follows:

Heating Period, Hours	4	6	8	10	24
Pyruvic acid, Milligrams	88.5	160.9	94.9	69.97	57.0

The decrease in yields for heating periods beyond 6 hrs., the indicated optimum, could be due either to decomposition of the acid or to its polymerization. Since tests for carbon dioxide were negative, it was probably the latter.

Reaction of Dibenzyl with Selenium Dioxide. Dibenzyl when heated with selenium dioxide at 300°C. yields stilbene and benzil.

a) $SeO_2+2C_6H_5-CH_2-CH_2-C_6H_5 \rightarrow 2C_6H_5-CH=CH-C_6H_5+Se+H_2O$

b) $2SeO_2+C_6H_5-CH_2-CH_2-C_6H_5 \rightarrow C_6H_5-CO-CO-C_6H_5+2Se+2H_2O$

Mixtures of varied molar quantities of the reactants, contained in sealed Pyrex tubes, were placed in an electrically heated tube furnace and

[1]Compiled from a thesis presented in partial fulfillment of the requirements for the degree Ph.D.

[2]H. L. Riley, J. F. Morley, and N. Friend, 1932. Jour. Chem. Soc. **1932**:1875.

[3]H. L. Riley and N. Friend, 1932. Jour. Chem. Soc. **1932**:2342

[4]S. Astin, A. Neuman, and H. L. Riley, 1933. Jour. Chem. Soc. **1933**:391. Astin and Riley, 1934. Jour. Chem. Soc. **1934**:844.

[5]S. Astin, L. deV. Moules, and H. L. Riley, 1935. Jour. Chem. Soc. **1935**:901.

[6]E. Schwenk and E. Borgwardt, 1932. Ber. **65**:1601.

[7]R. Müller, 1933. Ber. **66**:1668.

[8]C. H. Fisher, 1934. Jour. Amer. Chem. Soc. **56**:2056.

[9]J. J. Postowsky and B. P. Lugowkin, 1935. Ber. **68**:852.

[10]H. Wieland, 1924. Ann. d. Chem. **436**:229.

[11]W. B. Wendel, 1932. Jour. Biol. Chem. **94**:719.

maintained at the reaction temperature for periods of 1.5 to 18 hours. The constituents of the reaction mixture, stilbene, benzil and dibenzyl, were separated and quantitatively determined by an especially devised method,[12] as follows: The reaction mixture was dissolved in methanol and the volume brought to 500 ml. To 100 ml. of this solution were added 5 g. of hydroxylamine hydrochloride and 5 drops of concentrated hydrochloric acid. The mixture, after heating for one hour on a water bath to complete the formation of benzil oxime,[13] was distilled with steam, until 2000 ml. of distillate were collected, to carry over the stilbene and dibenzyl. The combined weight of these substances was obtained by ether extractions of the distillate, evaporation of the ether and weighing the dry residue. The weight of the benzil was obtained by difference.

Another aliquot portion, 100 ml., of the methanol solution was evaporated to dryness and the residue dissolved in carbon disulphide. To this solution was added a solution of bromine in carbon disulphide, and after 24 hours the insoluble di-brom stilbene was collected on a filter, washed with absolute alcohol, dried, and weighed and the weight of stilbene calculated.

The yields of benzil and stilbene, expressed as percentages of the selenium dioxide and of the dibenzyl used, are given in Table I.

TABLE I.

Hours at 300°C.	% Used for Diphenyl	Benzil SeO_2	% Used for Diphenyl	Stilbene SeO_2	Selenium Dioxide % Used
I. SeO_2 one mole; dibenzyl two moles.					
1.5	6.4	22.1	0.0	0.0	22.1
3.0	10.5	36.6	13.5	18.9	55.5
6.0	14.8	51.6	16.7	23.4	75.0
12.0	21.9	76.9	15.3	21.7	98.6
18.0	23.0	80.0	13.9	19.5	99.5
II. SeO_2 two moles; Dibenzyl one mole.					
3.0	50.1	43.4	9.5	3.3	46.7
12.0	95.6	89.8	4.4	1.6	91.4
III. SeO_2 one mole; Dibenzyl one mole.					
6.0	32.7	55.7	15.3	10.5	56.2
12.0	46.1	79.9	21.7	14.5	94.4

From the data in Section I of this table, it is evident that the reaction proceeds more rapidly at first because of greater concentration of reactants. In the period 6 to 12 hrs. the amount of benzil formed corresponds to 25.3% of the selenium used, while in the period 12 to 18 hrs. only 3.1% is formed. The maximum amount of stilbene is attained with the heating period of 6 hrs. The ratio of the starting materials

[12]The error of this method of analysis was found to be less than 0.5% when applied to a mixture of known quantities of the three substances.
[13]H. Grossman and J. Mannheim, 1916. Ber. **50**:708.

does not remain constant during the course of the experiment. As the selenium dioxide is depleted, the reaction slows, and a point is finally reached when the dioxide reacts more easily and rapidly with stilbene to produce benzil than with dibenzyl to form the intermediate product stilbene.

The ratio of the reactants in Section II is theoretical for the production of benzil, and the quantities of benzil resulting are larger but not in direct proportion to the length of the heating period.

Reacting equimolecular quantities (Section III), as expected, resulted in a greater yield of benzil than in the first group of experiments. However, the maximum stilbene formation was not attained at 6 hrs.

Reaction of Toluene with Selenium Dioxide. When 15 ml. of toluene was heated with 2.9120 g. selenium dioxide in sealed tube for 12 hrs. at 300° C., 0.5846 g. of benzoic acid was produced. This amount of benzoic acid is 27.4% of the theoretical for the selenium dioxide employed. Reduction of the excess of toluene in the mixture gave decreased quantities of the acid and increased amounts of tar. Theoretical quantities of the reactants, under the above conditions, yielded tar containing no trace of benzoic acid.

Phenols and Polyhydric Alcohols with Selenium Dioxide. Investigation of the effect of selenium dioxide on phenol, o- and p-amino phenol, and o- and p-cresol revealed each of these substances to be susceptible to vigorous attack by selenium dioxide at relatively low temperatures, yielding insoluble tarry resins in which expected or possible oxidation products could not be detected. Efforts to reduce the rapidity and vigor of the oxidation did not lead to more satisfactory results.

Anisole and o-, m-, and p-methyl anisole, when reacted with selenium dioxide at water bath temperatures, suffered loss of the methoxy group and yielded resins comparable to those produced from phenol and the cresols.

Ethylene glycol, glycerol, and an aqueous solution of gluconic acid, when heated at their respective boiling points with selenium dioxide, did not yield aldehyde, ketone, or other evidences of oxidation.

Reaction of Iso-eugenol with Selenium Dioxide. The report of Riley, Morley and Friend,[14] that buchu camphor is formed when menthone is oxidized with selenium dioxide, suggested the possibility of producing vanillin by the oxidation of iso-eugenol with selenium dioxide.

Mixtures of 2 g. acet-iso-eugenol in 25 ml. alcohol, and 1 g. selenium dioxide remained inactive at room temperature, but, at 50°C., selenium mixed with a carbon was rapidly precipitated. Traces of vanillin were recognized by means of the phloroglucinol color reaction applied to the hydrolyzed acetylated reaction product. The discrepancy between the amount of vanillin and the amount of dioxide reduced was thought due to the pronounced susceptibility of the methoxy- group to oxidation at low temperatures by selenium dioxide.

Reaction of Aniline with SeO_2 and the Inhibiting Action of H_2SO_4. Aniline when vigorously stirred with an alcoholic or aqueous solution of selenium dioxide at room temperature was not oxidized; however, at

[14] loc. cit.

30°C., aniline black was produced. An aqueous solution of aniline sulphate was not attacked by selenium dioxide at room temperature but yielded aniline black at 40°C. When 5% sulfuric acid was used as a solvent, the aniline sulfate was not attacked until a temperature of 50°C. was attained. The temperature at which the aniline is attacked by selenium dioxide was found to rise 10°C. for each increase of 5% in the concentration of sulfuric acid in the solvent up to 20%.

Summary

The investigation of the action of selenium dioxide on dibenzyl has been extended to include improved experimental technique, method of analysis, and larger yields of oxidation products.

Pyruvic acid is produced in small yield from the reaction of selenium dioxide with propionic acid.

Selenium dioxide attacks the methoxy- group on a benzene ring and burns it off at low temperature but does not attack either the primary or secondary alcohol groups of glycol or glycerol at their respective boiling temperatures.

Sulfuric acid exercises an initial inhibitory effect in the reaction of selenium dioxide on aniline.

Toluene is oxidized to benzoic acid at 300°C. by selenium dioxide.

Selenocyanation of Aniline

T. H. Chao and R. E. Lyons, Indiana University

The new and successful method of thiocyanation by means of cupric thiocyanate as proposed by Kaufmann and Kuechler[1] encouraged us to investigate the possibilities of selenocyanation of the aromatic nucleus by reactions with cupric selenocyanate under similar conditions.

Experimental

Sodium selenocyanate was prepared by dissolving pulverized selenium in a warm concentrated aqueous solution of the theoretical quantity of sodium cyanide, contained in a distilling flask. The major portion of the water was then evaporated by passing a stream of laboratory fuel gas through the reaction mixture maintained at about 90°C., and finally, by additions of absolute alcohol followed by continued evaporations, the residue was obtained as a dry mass, which was preserved in absolute alcoholic solution of about 8% concentration.

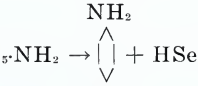
Cupric selenocyanate, prepared by reacting sodium selenocyanate with copper sulfate according to directions given by Fehling,[2] was unstable, decomposing rapidly into black cupric selenide and hydrogen selenide. No means was found for stabilizing or storing it without deterioration.

Para-selenocyano aniline—A yield of 40% was obtained by the following procedure: A mixture of 6 g. cupric acetate and 5 ml. acetic anhydride, to take up water of crystallization, was triturated constantly in a mortar during the gradual addition of 2.5 g. sodium selenocyanate in saturated absolute alcoholic solution and 0.5 g. aniline dissolved in 0.5 ml. glacial acetic acid. The reaction mixture after standing 0.5 hour was warmed to 60-65°C. for 2 hours, powdered and extracted with dry benzene. The p-selenocyano aniline obtained by evaporation, in partial vacuum, of the united benzene extracts was purified by resolution in warm benzene, adding dry gasoline until turbidity was established and warming until a clear solution resulted. Fine yellow needle like crystals (M.P. 85°C.) separated from the solution on standing and, after four recrystalizations from benzene-gasoline, melted with decomposition at 92-92.5°C. Our product was inactive with cold concentrated hydrochloric acid but turned red on boiling and, upon evaporation with acetic anhydride, yielded a white crystalline product (M.P. 206°C.). These deportments are in exact agreement with the properties of p-selenocyano aniline as reported by Challenger and co-workers.[3]

The reactions involved probably take place as follows:

(1) $Cu(CH_3{\cdot}COO)_2{\cdot}H_2O + 2NaSeCN \rightarrow Cu(SeCN)_2 + 2CH_3{\cdot}COONa + H_2O$

(2) $2Cu(SeCN)_2 \rightarrow 2Cu(SeCN) + (SeCN)_2$

(3) 

(4) $HSeCN \rightarrow HCN + Se.$

[1]H. P. Kaufmann and K. Kuechler, 1934. Ber. **67**:944.
[2]Herman V. Fehling, 1898. Neues Handwoerterbuch der Chemie. **6**:579.
[3]F. Challenger, A. T. Peters, J. Halvey, 1926. Jour. Chem. Soc. **1926**:1648. F. Challenger and A. T. Peters, 1928. Jour. Chem. Soc. **1928**:1375.

Attempts to extend this method of the synthesis of corresponding selenocyano compounds of toluene, chlorbenzene, monomethyl aniline, phenol, and anisol were unsuccessful. Moreover, the production of p-selenocyano aniline by this type of procedure was not satisfactory when mercuric acetate, ferric chloride, or stannic chloride was substituted for cupric acetate in the reaction mixture.

The Production of Hydrogen Selenide by Heating Paraffine with Selenium in the Presence of a Catalyst

T. H. Chao and R. E. Lyons, Indiana University

The production of hydrogen sulfide by heating hydrocarbons with sulfur has been widely studied and industrially applied. The production of hydrogen selenide by a similar process has been investigated by A. Etard and H. Moissan[1] employing colophene at a reaction temperature of 300°C. G. M. Weber[2] reported a poor yield by this method and stated that only 30.8% of the gas produced was hydrogen selenide. Green and Bradt[3] have reported that 1.0 g. of selenium heated at 380°C. with 50 g. paraffine-base motor oil for 1.0 hour produced 96.8% of the theoretical yield of hydrogen selenide and also that the yield of selenide from the mixture was negligible at temperatures below 300°C.

Scudder and Lyons[4] found that the production of hydrogen sulfide by heating hydrocarbons and sulfur could be catalyzed by finely divided carbon. The present work is a study of the effect of carbon in the mixture of paraffine and selenium for the production of hydrogen selenide.

Experimental

An intimate mixture of hydrocarbon, selenium, catalyst, etc., was placed in a 12x1 inch Pyrex test tube, equipped with a rubber stopper, through which were inserted a thermometer, a piece of tubing with fused-in stopcock, and a gas delivery tube leading to the absorption chamber, which contained a 5% solution of cupric sulfate to react with the hydrogen selenide, yielding cupric selenide as a precipitate.

The Pyrex tube was suspended in an electrically heated chamber. The thermometer bulb was in direct contact with the reaction mixture. At the end of the heating period, dry hydrogen was passed for 15 minutes through the glass-stopcocked tube into the reaction chamber to carry all hydrogen selenide into the copper solution. The cupric selenide was quantitatively collected on a weighed filter paper, washed, dried, and weighed.

A mixture of 10 g. white paraffine, M.P. 60°C., and 0.25 g. of powdered metallic selenium was heated to 360°-370°C. for 1 hour after the temperature of the reactants reached 360°C. and the hydrogen selenide calculated from the weight of cupric selenide recovered. The average of two experiments was 21.2% of theory.[5]

Accepting this as the normal yield obtainable under the described conditions, we planned a series of experiments to determine the effect of the presence of certain addition agents on the formation of selenide under the following conditions: Temperature, 360°-370°C.; time limit, 1 hour only after reactants reached 360°.

The data collected from a series of twelve experiments are given in Table I.

[1,2]J. W. Mellor, 1930. Treatise on inorganic and theoretical chemistry **10**:760.
[3]C. Green and W. E. Bradt, 1934. Proc. Indiana Acad. Sci. **43**:116.
[4]E. D. Scudder and R. E. Lyons. 1931. Proc. Indiana Acad. Sci. **40**:185.
[5]Green and Bradt reported a yield of 74.6% hydrogen selenide from heating 50 g. paraffine and 1g. selenium for 1 hour at 360°C.

TABLE I.

Exp.	Paraffine[1] g.	Selenium[2] g.	Pumice[3] g.	Addition Agent g.	H^2Se Yield %
1	10	0.25	0	0	21.2
2	10	0.25	0	Norite 3	45.0
3	10	0.25	5p	0	17.1
4	10	0.25	5p	Norite 3	63.7
5	5	0.125	5p	Norite 1.5	60.4
6	5	0.125	5c	Norite 1.5	75.0
7	5	0.125	5p	Bone Black 1.5	43.0
8	5	0.125	5c	Bone Black 1.5	45.9
9	5	0.125	5p	Charcoal[4] 1.5	57.4
10	5	0.125	5p	Lamp Black[5] 1.5	16.4
11	5	0.125	5c	Lamp Black 1.5	28.6
12	10	0.25	0	Norite 3	62.7

[1]White paraffine wax, M.P. 60°C.
[2]Finely powdered metallic selenium.
[3]Pumice: p (powdered); C (coarse—about ¼ inch dia.).
[4]Granular Coconut charcoal—about ⅛ inch dia.
[5]Wilkes, Martin Wilckes' "Ordinary Black".
[6]A repetition of Exp. 2, except the charge was heated for 2 hours after the temperature of the reactants reached 360°C.

Summary

It has been found that finely divided carbon catalyzes the reaction between paraffine and selenium for the production of hydrogen selenide. Of the four carbon preparations studied, Norite was found the most effective. Pumice served as a catalytic support only; it alone was found to have no positive catalytic effect.

Conductometric Titration of Iron, Aluminum, and Magnesium

E. W. Kanning and E. H. Lewis, Indiana University

Conductometric methods of analysis have been applied to a number of determinations involving precipitation reactions. I. M. Kolthoff[1] reports, in his monograph on conductometric titrations, successful results of titrations involving the determination of the following constituents:

1. Chloride, bromide, iodide, cyanide, thiocyanate, and chromate, using silver nitrate as reagent.

2. Chloride, bromide, iodide, cyanide, thiocyanate, formate, acetate, and its homologues, using mercuric perchlorate as reagent.

3. Iodide, ferrocyanide, ferricyanide, sulfate, pyrophosphate, sulfite, thiosulfate, oxalate, tartrate, succinate and benzoate, using lead nitrate as reagent.

4. Sulfate, chromate, carbonate, pyrophosphate, oxalate, tartrate, and citrate, using barium acetate or chloride as reagent.

5. Potassium at O°C., using sodium perchlorate as reagent. In addition to the determination of these common constituents, many others have been reported in the literature.

Since the hydroxides of ferric iron, aluminum, and magnesium are quite insoluble, it is logical that solutions of salts of these metals can be titrated conductometrically with sodium hydroxide solution to a definite end point. The purpose of this investigation was to determine the adaptability of conductance methods to the titration of these three metal ions by precipitation as hydroxides from neutral solutions of the chlorides.

Procedure

The titrations were carried out using a conductance cell of the dip type, the platinum electrodes having surfaces of 1.5 sq. cm. each, placed 3.5 cm. apart. It was found unnecessary to platinize the electrodes, as the bright platinum seemed to give somewhat better results. The solutions during the titrations were kept agitated by means of a mechanical stirrer and also maintained at a constant temperature in a water bath.

The resistance of the solution after each addition of the reagent was measured by means of a Leeds and Northrup 60 cycle A.C. galvonometer, No. 19123, and a resistance box, No. 75928.

Stock solutions of magnesium, aluminum, and ferric chlorides were prepared from the hydrated salts using carbon dioxide-free water. These solutions were standardized by gravimetric methods for the metal ion content. The sodium hydroxide solutions used in the titrations were prepared from carbon dioxide free-water.

Various volumes of the stock solutions, measured by means of pipets, were made up to 125 ml. and titrated with sodium hydroxide solution. With the exception of a few experiments, the titrations were carried out at 25°C.

The investigation was divided into four series of titrations: (1) titrations of magnesium chloride, (2) titrations of aluminum chloride,

[1]Kolthoff, I. M., Konduktometrische Titrationem. Dresden, 1923.

(3) titrations of ferric chloride, and (4) titrations of mixtures of two or more of the metal chlorides.

In all cases the end points in the titrations were determined graphically by plotting the resistance of the solution as ordinates and the volume of reagent as abscissa.

Results

The data in Table I show the results obtained in the first series of experiments involving the conductometric titration of neutral solutions of magnesium chloride with sodium hydroxide as reagent.

TABLE I. TITRATION OF MAGNESIUM CHLORIDE

Expt.	Magnesium Present Grams	Vol. of NaOH Theoretically Required ml.	Vol. of NaOH Actually Used ml.	Error[1] %
2[2]	0.0602	41.4	41.7	+0.33
16[3]	0.0481	29.2	29.5	+0.74
17[3]	0.0481	29.2	29.2	0 00
20[3]	0.0842	51.1	51.2	+0 05
21[3]	0.0842	51.1	52.0	+1.50
22[3]	0.1205	73.0	73.0	0 00
23[4]	0.1205	76.4	76.5	+0.33
24[4]	0 0602	38.2	39.0	+1.61
25[4]	0.0602	38.2	38.5	+0 33

[1]Error = Grams magnesium present minus grams magnesium found from the titration, divided by the grams magnesium present times 100.
[2]0.1192 N NaOH used.
[3]0.8353 N NaOH used.
[4]0.1292 N NaOH used.

In general it was found that the determination of magnesium by the precipitation of the hydroxide with sodium hydroxide can be carried out very successfully and accurately by the conductance method. The error involved in all the experiments cited is quite low and in some cases negligible. The end points of the titrations were clearly defined and easily determined from the conductance curves, an example of which is shown in Figure 1, which is typical of all the titrations in this series.

The effect of increased temperature on the titrations was determined by carrying out a few experiments at temperatures of 40°C., 50°C., 60°C., and 70°C. The elevated temperature decreased the accuracy of the determination of magnesium because of the difficulty in locating the end points of the titrations on the graphs, due to the fact that the curves flattened out in the neighborhood of the end points.

The results obtained in the experiments involving the titrations of solutions of aluminum chloride with sodium hydroxide indicate quite conclusively, as in the case of the titration of magnesium chloride, that the conductometric method is satisfactory in the volumetric determination

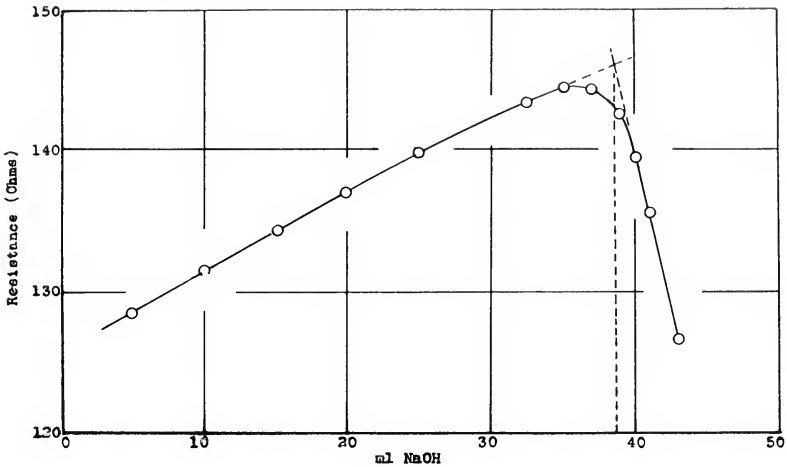


Fig. 1.

of aluminum by the precipitation as the hydroxide. The data for this series of experiments are shown in Table II.

The equivalence points for the quantitative separation of aluminum hydroxide are very clearly defined in the curves. A typical example is given in Figure 2. The formation of the aluminate is shown by a slight change in direction of the conductance curve. The greater the concentration of aluminum chloride in the original solution, the more distinctly

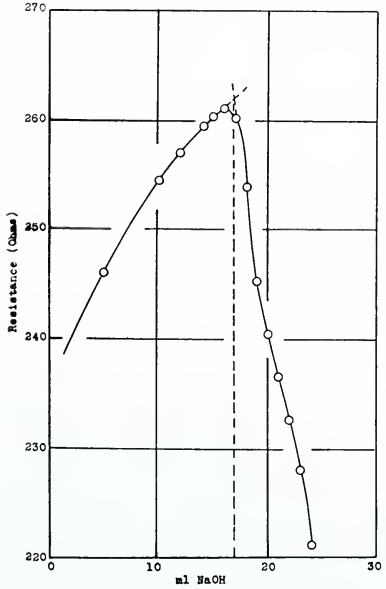


Fig. 2.

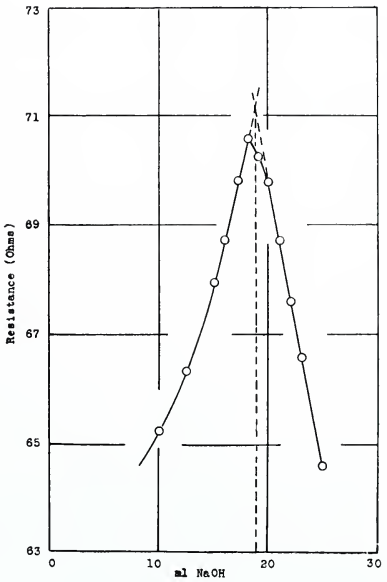


Fig. 3.

TABLE II. TITRATION OF ALUMINUM CHLORIDE

Expt.	Aluminum Present Grams	Vol. of NaOH[1] Theoretically Required ml.	Vol. of NaOH[1] Actually Used ml.	Error %
41	0.0101	8.50	8.50	0.00
42	0.0202	17.00	17.00	0.00
43	0.0253	21.20	21.00	−1.42
46	0.0354	29.70	29.70	0.00
47	0.0506	42.50	42.50	0.00
48[2]	0.0253	25.50	25.50	0.00

[1]0.1321 N NaOH was used.
[2]0.1095 N NaOH was used.

the aluminate formation was shown by the curves. In no case was the quantitative determination of the aluminate equivalence point possible.

The third series of experiments involved the titration of solutions of ferric chloride with sodium hydroxide. The error involved in these titrations was considerably greater than in the two previous series. In all cases the error was found to be a negative one. It may be possible that the colloidal nature of the ferric hydroxide precipitate effected the conductance of the solutions in such a manner as to interfere with the accurate indication of the equivalence points of the titrations. The addition of various salts to effect a precipitation of the colloid seemed to bear out this contention, since the accuracy of the determinations was greatly increased by the addition of sodium chloride to the solutions to be

TABLE III. TITRATION OF FERRIC CHLORIDE

Expt.	Ferric Ion Present Grams	Vol. of NaOH[1] Theoretically Required ml.	Vol. of NaOH[1] Actually Used ml.	Error %
60	0.0215	10.00	9.70	−3.02
61	0.0215	10.00	9.70	−3.02
62	0.0430	20.00	19.50	−2.20
63	0.0430	20.00	19.50	−2.20
64	0.0537	25.00	24.00	−3.82
65	0.0537	25.00	23.80	−4.63
66[2]	0.0753	34.40	33.00	−5.70
67[2]	0.0753	34.40	33.00	−5.70
68[2]	0.1076	49.10	48.00	−3.90
69[2]	0.1076	49.10	47.50	−4.08

[1]0.1156 N NaOH was used.
[2]0.1175 N NaOH was used.

titrated. The data for the ferric chloride series are shown in Table III. The conductance curves in this series are typified in Figure 3.

As far as this investigation has gone, the determination of ferric iron by titration of solutions of the chloride with sodium hydroxide is found to be only approximate, the error involved in the titrations preventing an accurate quantitative estimation.

The titration of mixtures of magnesium, aluminum, and ferric chloride with sodium hydroxide should, theoretically at least, give successive breaks in the conductance curves. With this in mind, definite mixtures of each of the three possible pairs and also mixtures of all three of the metal chlorides were titrated with sodium hydroxide for the purpose of a quantitative determination of each ion in the presence of one or more of the others.

The titration of mixtures of magnesium and aluminum chlorides yielded a large positive error in the equivalence point for the aluminum and a smaller positive error for the magnesium. The first break in the conductance curves was quite indistinct, in this case showing the precipitation of aluminum hydroxide. The second break, indicating the complete separation of magnesium hydroxide, was quite clear and yielded an accurate detection of the end point. From twelve titrations involving mixtures of magnesium and aluminum chlorides an average error in the estimation of aluminum was found to be +3.76%, and in the determination of magnesium, +0.31%. This series of experiments indicates a very accurate determination of magnesium in the presence of aluminum and a somewhat less accurate estimation of aluminum.

The conductometric titration of solutions of mixtures of ferric and magnesium chlorides with sodium hydroxide yields a large negative error for the estimation of ferric iron and a very small, nearly negligible, error for the determination of magnesium. The error in the case of the iron was due entirely to the difficulty in determining the point of inflection of the conductance curve which represented the equivalence point, since two distinct breaks in the curve occurred in the neighborhood of the iron end point.

From the experiments, the average error found in the determination of the ferric ion was −4.00%, and, for the determination of magnesium, +0.20%. From the data, it can be seen that a very accurate determination of magnesium in the presence of ferric iron can be carried out by a conductometric titration of the neutral chlorides with sodium hydroxide. However, the estimation of the ferric ion is only fairly accurate.

The titration of mixtures of ferric and aluminum chlorides gave results quite similar to the titration of mixtures of ferric and magnesium chlorides. The greater error was found at the first end point (ferric ion). From approximately ten experiments, the average error in the determination of the ferric ion was −2.72% and in the determination of the aluminum, −1.46%. From the data obtained, the determination of ferric iron and aluminum in the presence of each other by the conductance titration of solutions of the neutral chlorides with sodium hydroxide yields quite accurate results, the slight difficulty in locating the exact end point for the ferric ion preventing an exact determination of each ion involved.

The titration of solutions containing mixtures of the three ions yields results to be expected. The determination of aluminum and of magnesium is quite accurate, while the determination of the ferric iron end point involves considerable error. From an average of ten experiments, the error for the determination of each of the three ions was found to be: ferric, −6.13%, aluminum, +0.56%, and, magnesium, −0.94%.

As a conclusion, it is evident from the data given that the conductometric titration of solutions of magnesium, aluminum, and ferric chlorides with sodium hydroxide yields (1) accurate results for the following determinations:

a. Aluminum in solutions of aluminum chloride,
b. Magnesium in solutions of magnesium chloride,
c. Magnesium in solutions of magnesium and aluminum chlorides,
d. Magnesium in solutions of magnesium and ferric chlorides,
e. Aluminum in solutions of aluminum and ferric chlorides,
f. Magnesium and aluminum in solutions of magnesium, aluminum, and ferric chlorides,

and (2) fairly accurate results in the determination of:

a. Ferric iron in solutions of ferric chlorides,
b. Aluminum in solutions of magnesium and aluminum chlorides,
c. Ferric iron in solutions of magnesium and ferric chlorides,
d. Ferric iron in solutions of aluminum and ferric chlorides.

Catalytic Esterification with Dihydroxyfluoboric Acid

J. W. Kroeger, F. J. Sowa, and J. A. Nieuwland,[1] University of Notre Dame

The study of the chemistry of dihydroxyfluoboric acid has been the subject of recent investigations in this laboratory. The catalytic reactions, in particular, offer an especially fertile field of research since dihydroxyfluoboric acid is an active catalyst both alone and when combined with certain catalytic metals. As an esterification catalyst this compound combines the best features of hydrogen chloride and sulfuric acid in that it has little or no polymerizing action and is nonvolatile in ordinary esterification mixtures. (The pure acid boils at 159.1°.) This latter property makes possible the use of this catalyst in continuous esterification processes. Such a process was not actually carried out, but it was found that the catalyst could be used repeatedly without loss of activity, which fact indicates the feasibility of the use of dihydroxyfluoboric acid in continuous esterification.

In the majority of the preparations it was found that preliminary removal of the catalyst was unnecessary. Because of this, the pure ester could be obtained simply by fractionation of the crude reaction mixture with consequent improvement in the yield. Removal of the catalyst, when desired, could be effected by the addition of a solution of sodium methylate in methyl alcohol and subsequent filtration to remove the sodium salts formed.

In general, better yields were obtained in the esterification of aliphatic acids than with aromatic acids. Anthranilic acid gave only a 5% yield of the methyl ester. On the other hand, practically quantitative yields of certain aliphatic esters were obtained. Tert-butyl acetate could be prepared with this catalyst but only in very poor yields.

Dihydroxyfluoboric acid is most conveniently prepared in the laboratory by the action of boron trifluoride on solid orthoboric acid.[2] It can be handled in much the same manner as concentrated sulfuric acid, but it is much less corrosive on contact with the skin. Dihydroxyfluoboric acid when alone is decomposed by water to orthoboric acid, but, peculiarly enough, the water present in an esterification mixture seems to have no effect on the catalyst. Quite frequently it was found that the catalyst could be recovered unchanged after removal by distillation of the alcohol and organic acid and their reaction products.

Experimental

The majority of the esters were prepared in the following manner: The organic acid (0.5 to 1.0 mole) was placed in a 500 ml. flask with an excess of the anhydrous alcohol (3.0 to 6.0 moles) and 1 to 2% by weight of dihydroxyfluoboric acid was added. The flask was then fitted with a reflux condenser and the mixture was refluxed for 2 to 4 hours. The product was then fractionated to recover the pure ester.

[1]The major portion of this work was completed before the death of Rev. J. A. Nieuwland, June 11, 1936.

[2]Sowa, Kroeger, and Nieuwland, 1935. Jour. Amer. Chem. Soc., 57:454.

If removal of the catalyst was considered desirable, a solution of 5 g. of sodium in 25 ml. of methyl alcohol was added to the crude reaction mixture, and the resulting sodium salts were removed by filtration. The filtrate was then fractionated.

The following table (Table I) is a summary of the preparations of the various esters.

TABLE I.

Acid	Alcohol	B. P. Ester °C.	Yield %
Adipic[1]	Methyl	di-111-113°(9 mm.)	85
		mono-157-160°(9 mm.)	14 } 99
Sebacic[1]	Methyl	174-176°(22 mm.)	98
Oxalic[2]	Methyl	m.p. 52-53°	93
Succinic[1]	Methyl	87-89°(7 mm.)	74
Malic[1]	Methyl	m.p. 101-102°(Di methyl fumarate)	22
Tartaric[1]	Methyl	159-160°(20 mm.)	55
Anthranilic[3]	Methyl	132-136°(15 mm.)	5
Benzoic[1]	Methyl	195-198°(745)	19
Acetic[2]	Methyl	58-59°(748 mm.)	57
Acetic[2]	Ethyl	76-77°(748 mm.)	75
Acetic[2]	Isopropyl	89-90°(748 mm.)	85
Acetic[1]	Glycol	186-189°(746 mm.)	17

[1]Catalyst removed with sodium methylate.
[2]Purified without removal of the catalyst.
[3]The unreacted anthranilic acid was removed by washing with sodium bicarbonate solution and the ester was extracted with ether.

The dibasic acids mentioned in Table I were completely converted to the dimethyl esters with the exception of adipic acid which gave the results indicated.

A group of preparations of ethyl acetate were run to determine the effectiveness of the catalyst when used repeatedly. The procedure was as follows: The required quantities of acetic acid and absolute ethyl alcohol (see Table II) were weighed into a flask, and 2 g. of dihydroxyfluoboric acid was added. The mixture was refluxed for one hour; then the fraction boiling below 120° was removed by distillation. This fraction was washed with sodium carbonate solution, dried over calcium chloride, and distilled. This distillate consisted of pure ethyl acetate, b.p. 76°-77°.

Fresh acetic acid and alcohol were then added to the residue boiling above 120° (catalyst from first run). The mixture was again refluxed, after which the fraction boiling below the 120° was distilled off and purified as before. A series of eight runs gave the results summarized in Table II.

It may be noted that increase in either the time of reflux or the amount of alcohol caused a slight but definite increase in the yield. On the other hand, increase in the amount of acetic acid caused a decrease

TABLE II.

Number	G. Acetic Acid	G. Alcohol	Time of Reflux (hrs.)	Yield, G. Ethyl Acetate
I	60	46	1.00	42
II	60	46	2.25	48
III	60	46	2.25	47
IV	60	46	4.50	50
V	60	46	5.00	52
VI	60	56	5.00	53
VII	70	46	5.00	34
VIII	60	60	5.50	60

in the yield. This loss probably took place during the final purification of the ester.

On completion of the eighth run the residue boiling above 120° was transferred to a small flask and distilled. Of the original 2 g. of dihydroxyfluoboric acid used, 1.4 g. were recovered, b.p. 156°-158°.

Acknowledgment.—We are indebted to Mr. F. C. Weber for the preparation of several of these esters.

Summary

1. Dihydroxyfluoboric acid has been found to be an efficient catalyst for esterification reactions.

2. As a catalyst, it may be used repeatedly without loss of activity.

3. The preparation of a number of esters is described.

A Fractionation Column Employing Adsorbents

R. J. Hartman and D. H. Jung, Indiana University

Midgley (1) was first to point out that a column filled with carborundum instead of glass beads was better for the fractional separation of benzene and toluene. The adsorptive capacity of carborundum in a distilling column was further studied by Miss Esther C. Farnham (2). Conclusions were drawn that the chemical as well as physical structure of the column filling specifically affects the boiling temperature-composition curves. The specific action of such materials is probably due to selective adsorption of the passing vapors.

There is a specific adsorption by silica or carbon from binary organic mixtures. Adsorption from systems of various alcohols and benzene by silica (3) reveals that the alcohol in the system is highly adsorbed at low alcohol concentrations, and benzene is preferentially adsorbed at high alcohol concentrations. If, instead of silica, carbon is used as adsorbent, the amount of alcohol adsorbed is much less, due to the fact that adhesion tension values of the alcohols against carbon are lower than those of benzene against carbon.

Without doubt, the composition of the distillate can be affected by certain solid materials as adsorbents in the column. This investigation was carried out in order to study the specific adsorption of benzene-methyl alcohol vapor by various adsorbents in a specially constructed fractional distilling column.

Experimental

Materials and Apparatus.—The general methods were employed for purifying the benzene and methyl alcohol by means of dehydration and distillation.

The following adsorbents used in this investigation were commercial products supplied by various firms as indicated: alumina, 8-14 mesh, from Alcoa Ore Co., East St. Louis, Ill.; silica gel, ½ No. 150-G-600-014, from Silica Gel Corporation, Baltimore, Md.; coconut charcoal, granulated, from Eimer and Amend, New York City; and carborundum, No. 10RA, from the Carborundum Co., Niagara Falls, N. Y.

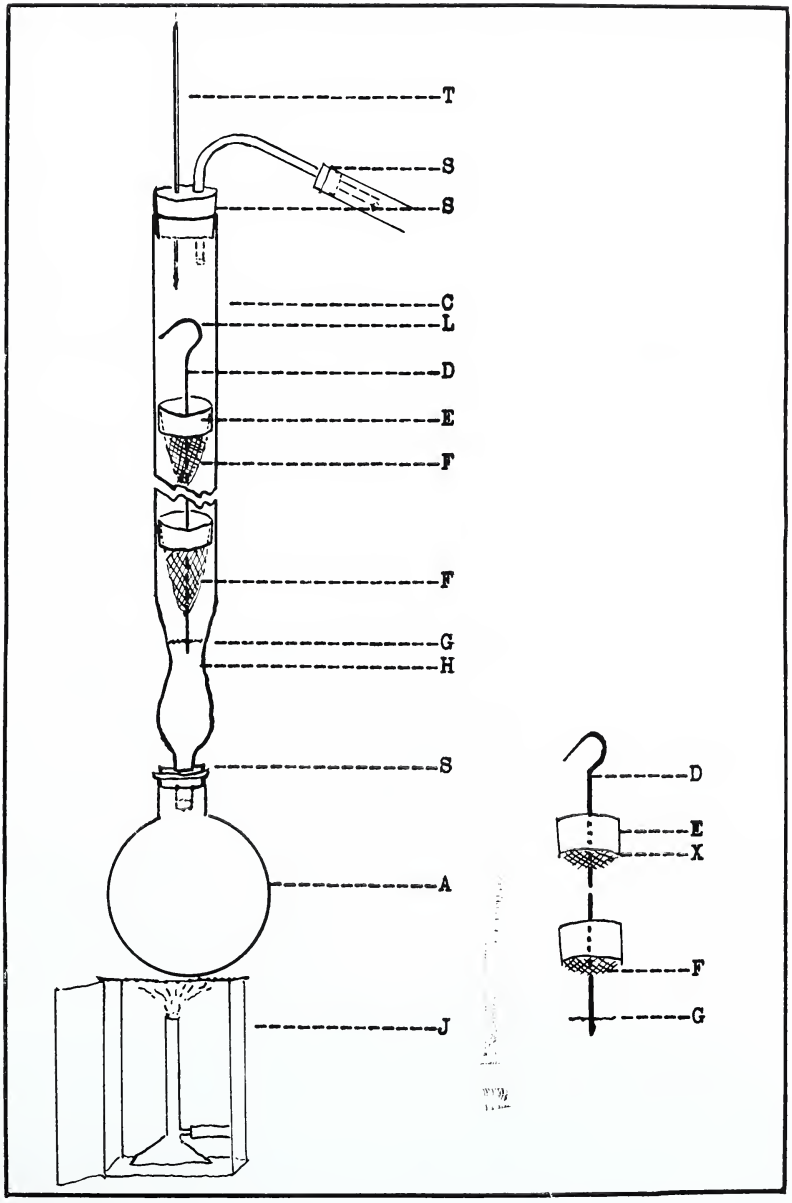
The adsorbents were activated for 8 hours at a temperature of 200°C. in a stream of air. They were immediately placed in a desiccator and used within ½ to 1 hour from the time of activation.

When an ordinary fractionation column filled with the adsorbent was used to separate the substances by distillation, it was found that the adsorbent was wetted by the condensed liquid. This rendered the adsorbent less efficient. In order to avoid this difficulty the distilling column shown in Figure 1 was designed.

The 500 cc. round-bottom pyrex flask *A* held 100 cc. of liquid to be distilled. The column consisted of a glass combustion tube *C*, 2.5 cm. inside diameter and 65 cm. long. The constriction *H* at the lower end held the coarse iron gauze disc *G*, which was tin soldered to the galvanized iron wire *D*. By this means the "ring core" was held in place.

The "ring core" was made from a galvanized iron wire *D*, 0.25 cm.

in diameter and 55 cm. in length, to which were tin soldered 20 cones *F*, 2.5 cm. long made from 30 mesh copper gauze. At the top and outside of each inverted copper gauze cone were soldered rings *E*, 1.7 cm. in



Figs. 1, 2.

diameter and 1 cm. in height made from thin sheets of galvanized iron. These rings supported the cones when filled with adsorbent.

The galvanized iron wire was bent in the shape of a hook at the top *L* to afford easy removal of the "ring core" and, at the same time, it received the condensed vapor as it dripped from the bulb of the thermometer, *T* (graduated in tenths of a degree Centigrade), thus conducting the liquid to the inner wall of the glass tube *C* and preventing the adsorbent contained in the inverted cones from becoming wet.

The cork stoppers *S* were wrapped with tin foil, and the flame from a Bunsen burner was protected with the asbestos shield *J*.

A "ring core" (Fig. 2) was first constructed in a manner similar to that described above except that in the place of cones made of copper wire gauze, a disc of iron gauze was soldered to the wire *D* and to the bottom of each ring *E*. This design was found less desirable than that shown in Figure 1 because the condensed descending liquid collected on the lower edge of the ring at *X*, causing the adsorbent contained in the ring to become wet. The "ring core" with cones, illustrated in Figure 1, showed no tendency whatever for the liquid to wet the adsorbent contained in the cones.

In order to determine the efficiency of the column, 100 cc. of a mixture of 50% by volume of 95% alcohol with 50% of water was distilled using the "ring core". The volume of the distillate collected at various temperatures was compared with a distillation carried out in exactly the same manner only without the "ring core". The rate of distillation was kept at 50 drops per minute.

Table I shows the volume of distillate collected at various temperature ranges with and without the "ring core".

TABLE I. APPROXIMATE EFFICIENCY OF "RING CORE"

Temperature Range °C.	Cc. Collected Without "Ring Core"	Total	Cc. Collected With "Ring Core"	Total
-80	45.2	45.2	48.0	48.0
80-83	1.0	46.2	.....	48.0
83-89	.2	46.4	.....	48.0
89-96	.5	46.9	.....	48.0
96-100	46.1	93.0	45.3	93.3

The volume of liquid remaining in the flask after the distillation was 3.2 cc. without and 3.0 cc. with the "ring core". The total volumes accounted for in these distillations were, therefore, 96.2 cc. without and 96.3 cc. with the "ring core".

The samples collected up to 80°C. in both cases were found to contain 93% ethyl alcohol by volume. Analysis was made by the specific gravity method.

The approximate efficiency of this "ring core" column without an adsorbent was found to be 90.10%. The Snyder's small column gave an efficiency of 73.1% (4).

Figure 3, curve 1, was obtained by plotting the figures of column 3 (Table I) against those of column 1, and curve 2 by plotting the figures of column 5 against those of column 1.

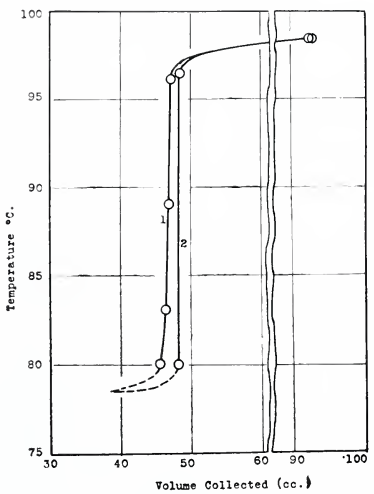


Fig. 3.

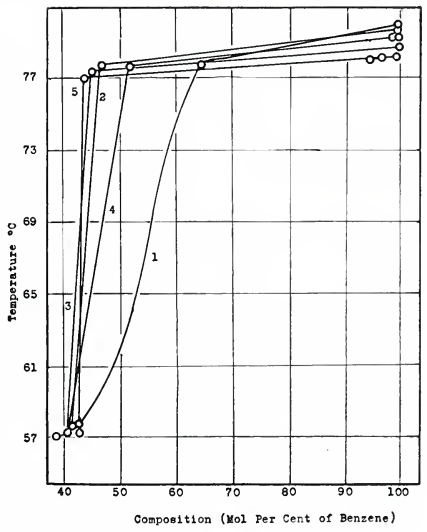


Fig. 4.

TABLE II. FRACTIONAL DISTILLATION OF 64.58 AND 35.47 MOL PER CENT OF BENZENE AND METHYL ALCOHOL RESPECTIVELY WITH "RING CORE" COLUMN USING VARIOUS ADSORBENTS.

No Adsorbent		18 Gms. Alumina		25 Gms. Carborundum		15 Gms. Cocoa-nut Charcoal		20 Gms. Silica	
Temp. °C.	Mol % C_6H_6	Temp. °C.	Mol % C_6H_6	Temp. °C.	Mol % C_6H_6	Temp. °C.	Mol % C_6H_6	Temp. °C.	Mol % C_6H_6
57.0	38.2	57.1	40.9	57.1	39.5	57.1	33.3	57.4	41.6
57.1	38.6	57.2	41.0	57.2	40.0	57.15	38.2	57.5	43.2
57.2	40.0	57.3	41.0	57.2	40.2	57.2	40.0	57.6	43.3
57.25	40.5	57.35	41.4	57.2	40.3	57.2	40.4	57.8	43.5
57.3	40.5	57.35	41.8	57.3	40.8	57.3	41.0	77.0	43.7
78.0	64.5	78.0	46.8	77.5	45.4	77.8	51.6	77.2	93.0
78.8	99.5	78.4	99.0	78.0	99.5	78.2	98.0	78.0	94.5
78.9	99.8	78.7	99.8	78.5	99.8	78.5	99.8	78.0	96.8
79.5	99.9	79.0	99.9	78.8	99.9	78.6	100.0	78.3	99.6
79.5	100.0	79.4	100.0	79.2	100.0	78.9	100.0	78.5	99.9

Procedure.—The apparatus illustrated in Figure 1 was used in all experiments. One hundred cubic centimeters of known composition of benzene and methyl alcohol was placed in the flask *A*. The cones of the "ring core" were immediately filled with activated adsorbent and put in place. The contents of the flask were heated with a constant low flame. The column was insulated with several wrappings of asbestos paper and hinged shields were used to protect the whole apparatus from draughts. The temperature for each 10 cc. portion of distillate collected was recorded and these samples were then analyzed by means of an Abbé refractometer.

Data and Results.—Table II gives the experimental results obtained when a mixture of 64.58 and 35.47 mol% of benzene and methyl alcohol, respectively, was distilled using the "ring core" fractionation column without an adsorbent and with alumina, carborundum, coconut charcoal, and silica as adsorbents.

Figure 4, curves 1-5, were obtained by plotting the data presented in Table II. The jump in temperature occurred in curve 1 (no adsorbent) when there still remained about 64.5 mol% of benzene in the distillate; curve 2 (alumina), 46.8%; curve 3 (carborundum), 45.4%; curve 4 (coconut charcoal), 51.6%; and, curve 5 (silica), 43.7%. Considering these figures and the position of the curves in Figure 4, carborundum or silica can be said to be more efficient than either alumina or charcoal in the separation by fractional distillation of the binary mixture of benzene and methyl alcohol. The jump in curve 5 is more abrupt than that in curve 3 showing that the separation is more definite when silica is used in the "ring core" in the place of carborundum. This is undoubtedly due to the specific adsorptive properties of these adsorbents.

A second series of experiments, using a mixture of 31.16 and 68.8 mol% of benzene and methyl alcohol, respectively, was performed in a manner exactly analogous to that described above. There was noted neither a decided jump in the boiling temperature nor a marked separation of benzene and methyl alcohol. When charcoal or silica was used, a sudden rise of temperature occurred at the beginning of the distillation. A much larger amount of methyl alcohol was absorbed by silica than by coconut charcoal evidently due to preferential adsorption (5).

In a third series of experiments a mixture of 10.14 and 89.8 mol% of benzene and methyl alcohol respectively was fractionally distilled. The results followed the same general course as those of the second series. Charcoal and silica again demonstrated the same irregularities as would be expected for a mixture richer in methyl alcohol.

It was noted that the curves obtained from the data of the second or third series of experiments came close together when the distillate contained about 18 or less mol% of benzene. The amount of adsorbent used was probably insufficient and became saturated with respect to methyl alcohol, thus causing the various adsorbents to behave similarly.

Summary

The distilling column described in this paper displayed two decided advantages. It not only has a high efficiency in itself, but it also affords

the study of the effect of the presence of various adsorbents in the column.

The mixture consisting of 64.5 and 35.47 mol% of benzene and methyl alcohol respectively was separated more completely on fractional distillation than either of the other two mixtures studied. The adsorbents studied in each case seemed to show individual differences in their ability to aid the separation of the mixture (benzene and methyl alcohol). Silica and carborundum acted better than either alumina or coconut charcoal, all of which are better than when no adsorbent whatever was used.

Considering the specific adsorption of adsorbents for benzene and methyl alcohol as pointed out in other investigations (3, 5, 6), the adsorbents used in this investigation behaved as would be expected.

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The Preparation and Properties of 2, 3, 4, 6-Tetraethyl-alpha-ethyl-*D*-glucoside[1]

W. W. Binkley with Ed. F. Degering, Purdue University

Numerous research studies have been devoted to the alkylation of the carbohydrates. The first methylating agent, introduced by Purdie and Irvine (1), to be applied successfully to α-methyl-*D*-glucoside was methyl iodide in the presence of silver oxide suspended in methyl alcohol. Somewhat later, Haworth (2) obtained comparable results by the use of methyl sulfate in the presence of aqueous sodium hydroxide. West (3) modified the Haworth procedure by using carbon tetrachloride as a solvent during the initial stages of the alkylation and succeeded in methylating *D*-glucose directly. Subsequently, using liquid ammonia as the solvent, Muskat (4) developed a method which permitted the use of either methyl iodide or methyl sulfate in the direct methylation of *D*-glucose. Padgett (5), by the use of modified Haworth and Irvine procedures, prepared and described 2,3,4,6-tetraethyl-α-methyl-*D*-glucoside. As his starting material, he used α-methyl-*D*-glucoside. The present study was undertaken with the hope of obtaining 2,3,4,6-tetraethyl-α-ethyl-*D*-glucoside by the direct ethylation of *D*-glucose.

Numerous variations of four different methods were investigated in the preparation of 2,3,4,6-tetraethyl-α-ethyl-*D*-glucoside. *D*-Glucose was treated with ethyl sulfate dissolved in carbon tetrachloride and neutralized with (a) aqueous sodium hydroxide, (b) normal butyl amine, (c) alcoholic sodium ethoxide, and (d) alcoholic sodium hydroxide. Some of the results obtained by the use of these different alkalies are given in Table I.

Table I. Relative Effect of the Different Alkalies

Method	First Step	Second Step	Base	Yield	% Yield	Remarks
a.1.	55°C.	70°C.	NaOH	1 g.	2.3	Rod stirrer
2.	70°C.	85°C.	NaOH	3 g.	6.8	Better stirring
3.	60°C.	82°C.	NaOH	7 g.	15.8	Good agitation
b.	65°C.	80°C.	$C_4H_9NH_2$	8 g.	18.0	Tarry product
c.	65°C.	80°C.	Et.ONa	1 g.	2.3	Good agitation
d.	65°C.	80°C.	Alc. NaOH	2 g.	4.5	Good agitation

Although 18 g. of material were obtained by Method b, the product contained an appreciable amount of tarry products; and the optimum conditions for ethylation were as follows: Twenty-five grams of *D*-glucose was dissolved in 15 cc. of water and added to a three-liter

[1]Abstract of thesis submitted to the faculty of Purdue University by W. W. Binkley in partial fulfillment of the requirements for the degree of Master of Science, August, 1936.

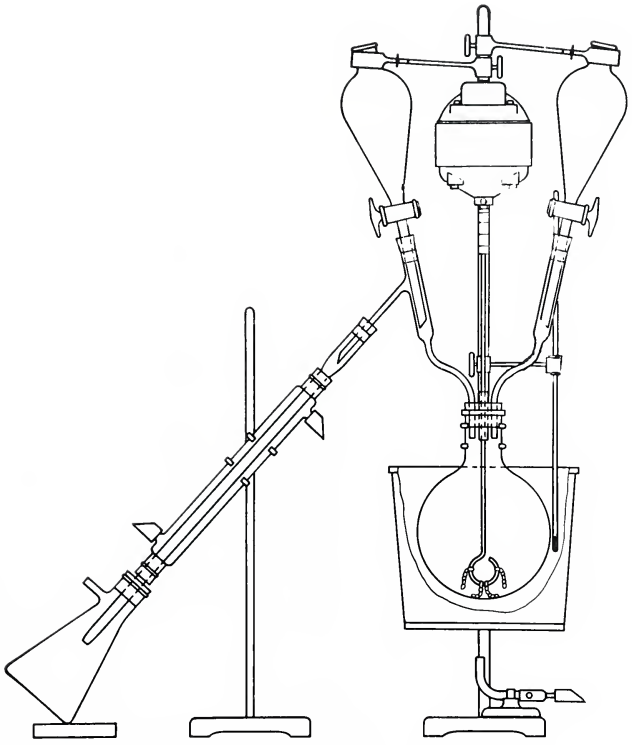

Fig. 1.

round-bottom flask which was equipped for vigorous agitation (Figure 1). Then 125 cc. of ethyl sulfate was dissolved in 125 cc. of carbon tetrachloride and added to the glucose solution. The mixture was agitated, the temperature of the bath raised of 65°C., and aqueous sodium hydroxide (340 g. NaOH dissolved in water and diluted to one liter) added dropwise from the dropping funnel until the carbon tetrachloride had distilled. One to one and one-half hours were required for this operation. Then, 500 cc. of 8.5 N sodium hydroxide was added rather rapidly through the other dropping funnel and the temperature of the bath raised to 85°C. The bath was maintained at about this temperature while 220 cc. of ethyl sulfate was added at the rate of about two drops per second. When the addition of the ethyl sulfate was completed, the temperature of the water bath was raised to boiling and held there for about thirty minutes, and the bath was then allowed to cool.

The mixture was extracted with six 100 cc. portions of chloroform, and the extracts were dried with anhydrous sodium sulfate, decolored by treatment with Norite, and filtered. The chloroform was removed by distillation under diminished pressure, and a light yellow sirup of crude 2,3,4,6-tetraethyl-α-ethyl-*D*-glucoside was obtained. The sirup was rectified in a modified Podbielniak column (Figure 2) to give a colorless

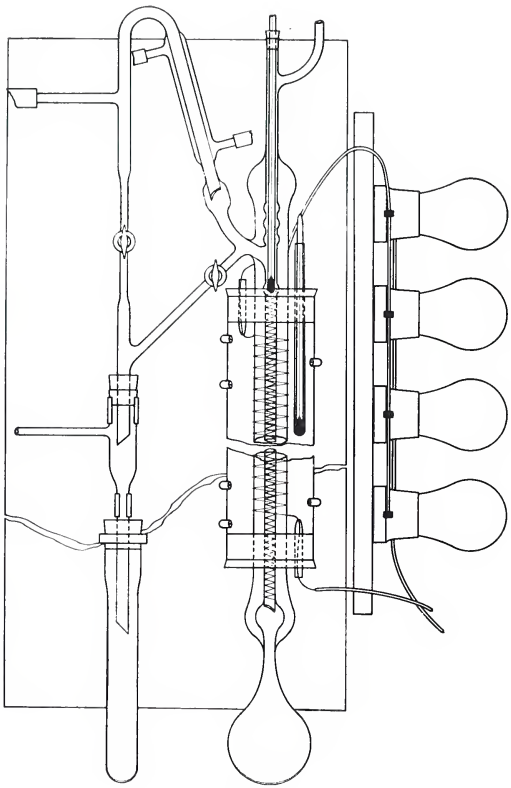

Fig. 2.

liquid which boiled at 99.8°C. at 0.2 mm. Its refractive index was found to be 1.4462 at 25°C. The average yield was seven grams. This product, when subjected to hydrolysis, gave the 2,3,4,6-tetraethyl-*D*-glucose described by Padgett (5).

The optimum conditions for the second step in the ethylation were determined by making a study of the ethylation of α-methyl-*D*-glucoside with ethyl sulfate in the presence of aqueous sodium hydroxide. The method of West and the method of Haworth were both studied. Some of these results are given in Table II.

The procedure used in Experiment 1a was as follows: Twenty-seven grams of α-methyl-D-glucoside was placed in the ethylation flask. To this was added 500 cc. of 8.5 N sodium hydroxide solution, the temperature of the bath was raised to 80°C., and 220 cc. of ethyl sulfate was added at the rate of about two drops per second. When the addition was completed, the temperature of the water bath was raised to boiling and maintained at that temperature for about thirty minutes and the bath allowed to cool. The product was isolated and purified as previously indicated. The average yield of crude material was 17 g.

In Experiment 2b, 27 g. of α-methyl-*D*-glucoside was placed in the

TABLE II.

Experiment	Bath Temperature	Method of	Base Used	Yield	% Yield
1a	80°C.	West	8.5 N NaOH	17 g.	39.4
b	80°C.	West	12.5 N NaOH	10 g.	23.2
c	80°C.	West	24.5 N NaOH	3 g.	6.9
2a	80°C.	Haworth	12.5 N NaOH	9 g.	18.6
b	80°C.	Haworth	8.5 N NaOH	16 g.	37.1

ethylation flask and 100 cc. of 8.5 N sodium hydroxide added to facilitate stirring. The temperature of the water bath was then raised to 80°C., and 220 cc. of ethyl sulfate was added at the rate of about two drops per second, while an additional amount (400 cc.) of 8.5 N sodium hydroxide was added at the rate of about four drops per second, or at such a rate as to maintain a slightly alkaline solution. This addition usually required about two hours. The bath temperature was then raised to boiling and maintained at that temperature for about thirty minutes and the bath allowed to cool. The product was isolated and purified as previously described. The yields were 16 to 20 g.

Summary

The following factors appear to be involved in the preparation of 2,3,4,6-tetraethyl-α-ethyl-*D*-glucoside: (1) vigorous agitation, (2) a suitable base in the proper concentration, and (3) the optimum temperature.

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Lecture Demonstrations in Organic Chemistry

Ed. F. Degering, Purdue University

Confronted with the problem of offering laboratory instruction to more students than our laboratories could accommodate, we resorted to the use of lecture demonstrations as a substitute for regular laboratory work in undergraduate organic laboratory chemistry.

These demonstrations are being offered to a group of beginning students in organic chemistry who are majoring in the field of home economics. With respect to this course, there are three points that deserve special emphasis: first, these demonstrations are intended for small groups of students, numbering about twenty to twenty-five to the section; second, two hours of outside preparation are required of the student before coming to class; and, third, these demonstrations are offered to students who are not majoring in chemistry and whose subsequent training will not be handicapped by the omission of this particular laboratory work.

In order to assure ourselves that the students do spend time in preparing for the exercise, reports on the topic under consideration are required to be handed in at the beginning of the demonstration hour. Further, to insure methodical preparation of this outside work, the reports are graded, and five to ten minute quizzes over the assignment are frequently given at the beginning of the demonstration hour. The lecture hour is devoted to the informal demonstration exercise and two hours to the preliminary outside preparation, meeting the usual requirement of three hours work for one hour of college credit.

The experiment selected as illustrative of the method is a comparatively simple one, namely, the preparation and properties of acetylene. The demonstration takes form somewhat as follows:

Acetylene is normally prepared by the action of water on calcium carbide;

$CaC_2 + 2\ H_2O \rightarrow H{\cdot}C{:}C{\cdot}H + Ca(OH)_2$.

Acetylene and other members of the series may be prepared by (a) the removal of two equivalents of "HX" from certain dihalogen compounds, as

$CH_3{\cdot}CH_2{\cdot}CHBr_2 + 2\ KOH$ (powdered) $\rightarrow CH_3{\cdot}CCH + 2\ KBr + 2\ H_2O$, (b) the removal of four equivalents of "X" from certain tetrahalogen compounds, as

$CH_3{\cdot}CBr_2{\cdot}CHBr_2 + 2\ Zn$ (ethyl alcohol and acetic acid) $\rightarrow CH_3{\cdot}CC{\cdot}H + 2\ ZnBr_2$,

or (c) by condensing metallic acetylides with alkyl halides as illustrated by the following equation;

$CH_3{\cdot}CC{\cdot}Na + X{\cdot}R \rightarrow CH_3{\cdot}CC{\cdot}R + NaX$.

From the laboratory viewpoint, the first method proves to be the most economical and satisfactory for the preparation of acetylene.

About five grams of calcium carbide are placed in a 50 cc.–distilling flask which is mounted on a ring stand and fitted with a dropping funnel. The side neck of the flask is connected with a bend of glass tubing in such a way that the gas may be collected by displacement of water from five-inch test tubes. After collecting samples of the gas, the following reactions are considered and the simpler ones illustrated.

The chemical properties of the "-yne" compounds may be characterized by:

1. Their tendency to burn with a smoky flame and to form explosive mix-

tures with air. Both of these properties are less pronounced in the case of "-ene" compounds, and still less observable in the case of the "-ane" compounds.

2. Their capacity to enter into addition reactions, as summarized below, when treated with (a) alkaline permanganate solution, halogens, or ozone, (b) molecular hydrogen in the presence of a catalyst or hydrogen from appropriate reducing agents, and (c) halogen acids, sulfuric acid, oxides of nitrogen, hypohalous acids, and similar compounds.

a. Oxidative addition

$$CH_3 \cdot C \overset{\downarrow}{=} \overset{\downarrow}{C} \cdot H$$

OH OH
Cl Cl
Br Br
I I/(alcohol)
O_3

b. Reductive addition

$$CH_3 \cdot C \overset{\downarrow}{=} \overset{\downarrow}{C} \cdot H$$

H H

c. Simple addition

$$CH_3 \cdot C \overset{\downarrow}{=} \overset{\downarrow}{C} \cdot H$$

Cl H
Br H
I H
$HO \cdot SO_2 \cdot O$ H
ONO NO
OH X

Only the initial stages of the reaction are indicated.

3. Polymerization, when passed through a hot tube, to give well defined derivatives;

3 H·C:C·H, passage through a hot tube $\rightarrow C_6H_6$ (benzene)

4. Substitution reactions involving the hydrogen atom attached to a carbon atom, which is attached in turn to another carbon atom by a triple bond. Specific examples are;

$H{:}CC \cdot H + 2\ Cu(NH_3)_2Cl$, aq.$\rightarrow Cu \cdot CC \cdot Cu + 2\ NH_4Cl + 2\ NH_3$, and

$H \cdot CC \cdot H + 2\ Ag(NH_3)_2NO_3$, aq.$\rightarrow Ag \cdot CC \cdot Ag + 2\ NH_4NO_3 + 2\ NH_3$.

In conclusion, the "-yne" compounds may be prepared from calcium carbide, from dihalogen compounds, from tetrahalogen compounds, or from acetylides. The principal chemical properties of the "-yne" compounds, aside from burning, are characterized by (a) three types of addition reactions, (b) polymerization to give well defined derivatives, and (c) substitution to give acetylides.

The Preparation and Properties of Some Ethoxy Compounds

NED GUTHRIE, Hanover College

This work is the result of an attempt to prepare alpha-amino-beta-hydroxy-acids by the following reactions:

(1) $CH_3CHO + C_2H_5OH + HCl \rightarrow CH_3CHClOC_2H_5 + H_2O$

(2) $CH_3CHClOC_2H_5 + Br_2 \rightarrow CH_2BrCHBrOC_2H_5 + HCl$

(3) $CH_2BrCHBrOC_2H_5 + RMgBr \rightarrow CH_2BrCH(R)OC_2H_5 + MgBr_2$

(4) $RCH(O\text{-}C_2H_5)-CH_2Br + NaCN \rightarrow RCH(O\text{-}C_2H_5)-CH_2CN + NaBr$

(5) $RCH(O\text{-}C_2H_5)-CH_2CN + 2HOH \xrightarrow{HCl} RCH(O\text{-}C_2H_5)-CH_2-COOH + NH_4Cl$

(6) $RCH(O\text{-}C_2H_5)-CH_2-COOH + Br_2 \rightarrow RCH(O\text{-}C_2H_5)-CHBr-COOH + HBr$

(7) $RCH(O\text{-}C_2H_5)-CHBr-COOH + NH_3 \rightarrow RCH(OC_2H_5)-CHNH_2-COOH + NH_4Br$

(8) $RCH(O\text{-}C_2H_5)-CHNH_2-COOH + HBr \rightarrow R-CH(OH)-CH(NH_2)-COOH + C_2H_5Br$

The first three reactions were carried out according to Boord. The first reaction was carried out by passing 100 g. of hydrogen chloride gas, dried over anhydrous calcium chloride, into an ice-cold mixture of paraldehyde and absolute ethyl alcohol. This requires about two hours time. The reaction mixture separated into two layers. The lower layer was discarded, and the upper layer was dried over anhydrous calcium chloride. Suction was used to remove any excess hydrogen chloride gas. This crude product was not distilled since distillation would cause too much decomposition.

The second reaction was carried out by treating the crude product from the first reaction with the theoretical amount of bromine in an ice bath kept at a temperature between 0° and 5°C. Hydrogen chloride gas was evolved. Calcium chloride was added, and the product was kept under suction for several hours to remove the hydrogen chloride gas which was formed. The product, a pale straw-colored liquid, was not distilled but was used directly in the third reaction.

The product of the second reaction was mixed with twice its volume of dry ether, cooled, and added slowly to a slight excess of alkyl magnesium bromide. After this reaction had taken place, the mixture was decomposed by pouring on ice and acidifying with hydrochloric acid. The ether layer separated. The ether extract of the aqueous layer was added to the ether layer and both dried over anhydrous sodium sulfate. The

ether was removed by distillation, and the remaining liquid was purified by steam distillation and then separated from the upper aqueous layer and dried over anhydrous sodium sulfate. This treatment destroyed any unchanged dibromo-ether, which was the product of the second reaction.

The product of the third reaction was refluxed with very slight excess of sodium cyanide, with sufficient quantities of ethyl alcohol and water to dissolve the ethoxybromide and also the sodium cyanide. The time of refluxing was 24 hours. Longer periods of refluxing did not increase the yields to any appreciable extent. The reaction mixture was then cooled and made neutral to litmus with hydrochloric acid and the alcohol removed through a fractionating column. The remaining liquid was again cooled and acidified and then extracted several times with ether. The ether extract was washed with sodium bicarbonate to remove any acids. The ether extract was then dried over anhydrous sodium sulfate and the ether removed by distillation. The nitrile was then fractionated under a pressure of one millimeter of mercury, the ethoxybromide distilling first and the ethoxy-nitrile distilling at a higher temperature.

The sodium bicarbonate washing was acidified and then extracted with ether and dried and the ether removed by distillation. Very little residue was left, thus showing that no acids were formed under these conditions.

When the alcohol was removed through a fractionating column in the fourth reaction, without the mixture being made neutral, some nitrile was formed and also some dibasic acid. When the alkyl group was ethyl, a yield of 18% of the nitrile was obtained, and a solid acid was identified as ethyl succinic acid by its melting point, neutral equivalent, and solubility. The melting point found was 95-96; that reported in the literature is 98. The neutral equivalent was 73, which checks with the calculated value. The compound was very soluble in water and insoluble in petroleum ether, as would be expected. The possible mechanism for this reaction is being further investigated. The following is suggested:

(1) $$\mathrm{RCH(O\text{-}C_2H_5)—CH_2CN \xrightarrow{Base} RCH=CHCN + C_2H_5OH}$$

(2) $$\mathrm{RCH:CHCN + HCN \rightarrow RCH(CN)-CH_2CN}$$

(3) $$\mathrm{RCH(CN)—CH_2CN + 4HOH \rightarrow RCH(COOH)—CH_2COOH + 2NH_3}$$

The hydrogen cyanide and the base for these reactions are formed by the hydrolysis of sodium cyanide.

In the fifth reaction, the product of reaction four was hydrolyzed with concentrated hydrochloric acid at 100°C. for two and one-half hours. On cooling, a white solid, ammonium chloride, separated out. Water was added to dissolve the ammonium chloride, and the mixture was extracted with ether. The ether extract was washed with water to remove hydrochloric acid and dried and the ether removed by distillation. The beta

ethoxy-acid distilled at 112-113°C. under a pressure of one millimeter of mercury. The neutral equivalent checked with the calculated value when the alkyl group was ethyl. When the hydrolysis was carried out at 60° C., a solid melting at 88-89° C. was isolated, which was the amide of the acid.

For the bromination of the ethoxy-acid, three attempts were made when the alkyl group was ethyl. In the first attempt, bromine and the acid were mixed and heated to 70°C., when some hydrogen bromide was evolved. The liquid remaining was extracted with chloroform, treated with sodium sulfite to remove excess bromine, and dried over anhydrous sodium sulfate. The chloroform was removed by distillation under reduced pressure. Only decomposition products of low boiling point were obtained. In the second attempt to brominate the ethoxy-acid, the bromine was mixed with the acid and kept in ultra-violet light. Hydrogen bromide was evolved, and decomposition products were again formed. In the third attempt to brominate the ethoxy-acid, the acid chloride was prepared by using thionyl chloride. The acid chloride was then brominated, hydrolyzed, extracted with ether, and dried and the ether removed by distillation. A liquid boiling at 98-100°C. under a pressure of one millimeter of mercury was obtained. The neutral equivalent of the acid was found to be 182.8, which corresponds to alpha-bromo-valeric acid, which has a neutral equivalent of 181.

Bromination was given up at this point and work with various Grignard's started in order to prepare following compounds and observe data listed below:

Alkyl Group Used	Ethyl	Propyl	Butyl
Yield of Nitrile	50%	35%	30%
Boiling Point of Nitrile (1mm.)	47-48°C.	64-66°C.	78-80°C.
Index of Refraction of Light	1.4200	1.4252	1.4260
Melting Point of Amide	88-89°C.	.....	.....
Boiling Point of Acid (1 mm.)	112-113°C.	.....	.....
Melting Point of Alkyl Succinic Acid	96°C.	.....	81°C.

Further work is being carried out to improve and also determine the yields for other groups besides the ethyl.

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Esterification in the Presence of Anhydrous Salts[1]

F. M. Whitacre and H. T. Briscoe, Indiana University

The use of anhydrous salts as catalysts in the reaction between ethyl alcohol and acetic acid was first mentioned by Berthelot and Pean de St. Gilles[2] in 1862 when they made a study of the equilibrium percentages of ethyl acetate formed by the reaction of acetic acid with various concentrations of ethyl alcohol.

This work was followed by investigations of Bogojawlensky and Narbutt[3] in 1905, Haberman and Berzina,[4] in 1909, and Haberman and Kurtenacher[5] in 1910, who found ferrous, nickel, copper, manganese, and zinc sulphates to be effective catalysts. N. G. Gajendraged[6] studied the reaction between ethyl alcohol, methyl alcohol, and acetic acid at 230°C. in the presence of potassium-aluminum sulphate and silica and reported the equilibrium constant to be in good agreement with that obtained by other workers in the liquid phase at lower temperatures. Whitacre and Briscoe[7] reported data obtained at 45°C. and 100°C. for the reaction between ethyl alcohol and acetic acid in the presence of various anhydrous salts. Some preliminary work in the gaseous state was also reported at this time.

This paper is a study of the reaction between the vapors of ethyl alcohol and acetic acid when passed over varied amounts of aluminum and copper sulphate.

Experimental Part

Apparatus. Much difficulty was encountered in designing and constructing a suitable apparatus for this problem. The apparatus shown in Figure 1 gave reproducible results. It was constructed entirely of Pyrex so that the liquid or gas came in contact with glass only.

Materials. The acetic acid used was glacial acetic having a gravity of not over 1.0510 at $\frac{20°C.}{4°}$. Ethyl alcohol was prepared by the usual methods. No alcohol was used which had a gravity greater than 0.7900 at $\frac{20°C.}{4°}$.

Alcoholic potassium hydroxide was used for titration because it was thought that in some cases it would be necessary to saponify the ester formed in order to obtain the required information concerning the progress of the reaction. The potassium hydroxide was standardized against weighed quantities of acetic acid and the standardization was checked with succinic acid.

[1]Part II of a thesis presented by F. M. Whitacre to the Graduate School of Indiana University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.
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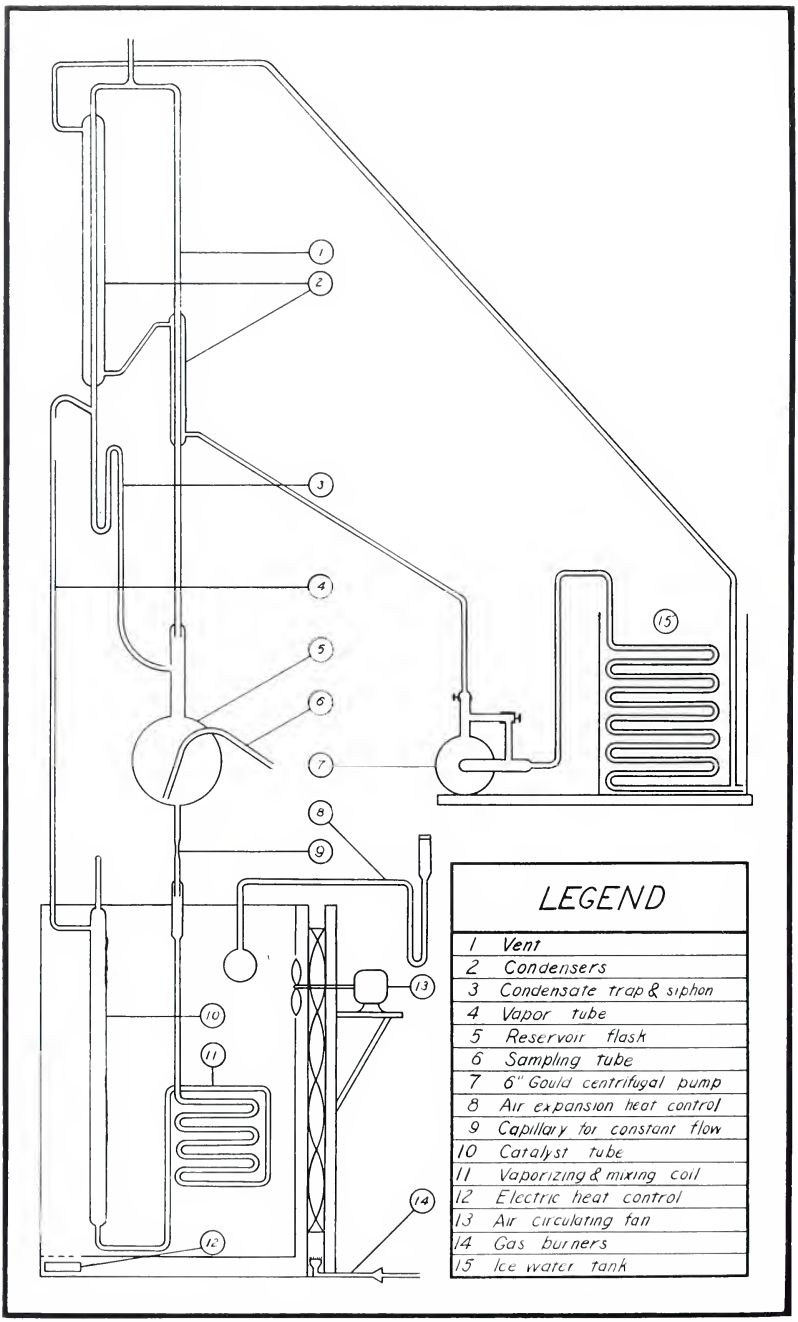
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3 Condensate trap & siphon
4 Vapor tube
5 Reservoir flask
6 Sampling tube
7 6" Gould centrifugal pump
8 Air expansion heat control
9 Capillary for constant flow
10 Catalyst tube
11 Vaporizing & mixing coil
12 Electric heat control
13 Air circulating fan
14 Gas burners
15 Ice water tank

Fig. 1.

TABLE I. EXPERIMENTAL DATA

(a) (See Curve (A) Fig. II) Glass Wool	
Time in Hours	Per Cent of Acid Converted
5.0	2.10
14.5	5.70
24.0	9.00
48.0	17.00
72.0	23.00
96.0	27.00
(b) (See Curve (B) Fig. II) 3.42 g. $Al_2(SO_4)_3$	
5.0	11.30
17.0	33.20
24.0	47.90
40.0	72.15
48.0	79.05
72.25	81.75
89.0	80.80
(c) (See Curve (C) Fig. II) 17.1 g. $Al_2(SO_4)_3$	
5.5	30.80
10.5	58.60
11.5	61.60
22.0	67.90
2.0	12.60
5.0	29.40
10.0	56.20
8.0	47.50
23.0	66.40
29.0	64.00
(h) (See Curve (H) Fig. II) 34.2 g. $Al_2(SO_4)_3$	
2.0	42.00
3.0	53.20
5.0	59.00
(d′) (See Curve (D′) Fig. II) 10.25 g. $Al_2(SO_4)_3$	
(a) 3.0	30.00
6.0	23.80
9.0	6.40
(b) 2.0	21.00
5.0	46.25
17.0	61.10
23.0	57.10
(d″) (See Curve (D″) Fig. II) 20.52 g. $Al_2(SO_4)_3$	
1.75	25.20
4.0	50.10
5.0	53.50
9.5	65.20

(d) (See Curve (D) Fig. II) 30.78 g. $Al_2(SO_4)_3$	
Time in Hours	Per Cent of Acid Converted
1.25	14.30
2.5	27.60
5.25	56.40
20.50	63.10
(e) (See Curve (E) and Fig. II) 26.4 g. $Al_2(SO_4)_3$	
(a) 2.0	58.30
3.0	65.10
(b) 1.25	20.80
4.25	68.92
4.75	68.90
(c) 1.25	25.60
4.0	71.00
5.0	76.15
23.25	77.85
(d) 0.75	32.70
1.50	54.90
2.0	61.90
4.0	63.60
6.0	58.00
(f) (See Curve (F) Fig. II) 68.1 g. $Al_2(SO_4)_3$	
(a) 0.5	38.60
1.0	52.15
(b) 0.5	42.30
0.75	55.40
1.25	60.22
(c) 0.166	14.80
2.75	61.18
5.0	61.70
(g) (See Curve (G) Fig. II) 110.0 g. $Al_2(SO_4)_3$	
0.1	51.80
(z) (See Curve (Z) Fig. II 30.78 g. $Al_2(SO_4)_3$	

The Reaction:

$$2HAc + EtOEt \rightarrow 2EtAc + H_2O$$

$$C_2H_5-O-C_2H_5 + 2CH_3COOH \rightarrow 2C_2H_3OOCCH_3 + H_2O$$

Ether, 103.9 c.c. Acid, 114.6 c.c.

20.52 g. $Al_2(SO_4)_3$	
7.25	1.75
19.25	5.80
29.0	12.25
42.25	23.80
51.5	26.20
67.0	26.80
71.5	4.50

The catalyst used here has been referred to in the discussion of Curve (Z).

The anhydrous copper sulphate was prepared by dehydrating the pentahydrate at 200°C. in the oven of the apparatus.

The aluminum sulphate was prepared in two ways. *Method I:* The hydrated salt was placed directly in the oven of the apparatus (200°C.). This produced a spongy easily pulverized mass. *Method II:* The hydrated salt was heated at 100°C. for 10 to 12 hours and then placed in the oven at 200°C. until needed. This produced a hard sintered mass which was broken up in a mortar. The particles used as the catalyst were those that passed through a ten-mesh screen and were retained by a twenty-mesh.

Experimental Procedure.—Acid and alcohol were removed from stock bottles, which were kept in a water bath at 25°C., and placed in separate burettes. Fifty ml. each of acid and alcohol was run from the burettes into a 250 ml. flask. This operation was carried out quickly in order to prevent any more than the unavoidable amount of air coming in contact with the reactants and to prevent the temperature from changing appreciably. The 250 ml. flask was tightly stoppered, and the mixture was violently shaken. A sample of this mixture was transferred to a small, accurately calibrated, water-jacketed 10 ml. burette. This sample was titrated with potassium hydroxide and recorded as "zero per cent acetic acid converted." The remainder of the mixture was placed in the storage bulb of the apparatus. The velocity of flow was adjusted so that the entire reaction mixture would pass over the catalyst in a certain time, say one hour. This velocity was kept constant at 1.66 ml. per minute during the entire investigation with noted exceptions. The temperature of the oven was maintained at 200°±5°C. during the entire investigation. The data are given in Table I.

Discussion of Data

These data are presented graphically in Figure 2 on log-log paper, which proves to be a convenient way of following the course of a reaction of this type.

In Curve A practically equimolecular quantities of alcohol and acid were passed through the apparatus with a plug of glass wool in the catalyst space. If this is compared with Curve 1 it will be seen that the reaction follows practically the same line in the gaseous phase at 200°C. as it does in the liquid phase at 45°C. The slope of this line between 2.5% and 15% acid converted is 0.35.

Curve B graphically represents the data obtained when a 3.42 g. portion of aluminum sulphate prepared by Method I is used. It will be seen that the equilibrium percentage is above 80%. This was caused by improper combustion in one of the gas burners which caused the temperature of the oven to fall to 170°C. after 30 hours of the run had been followed. The slope of this curve between the 10% and 40% points is 1.92.

Curve C presents the results of two runs after 13.68 g. of aluminum sulphate prepared by Method I was added to the original 3.42 g. in Curve B. The total weight of catalyst is 17.1 g. The slope between the 10% and 40% points is 5.54.

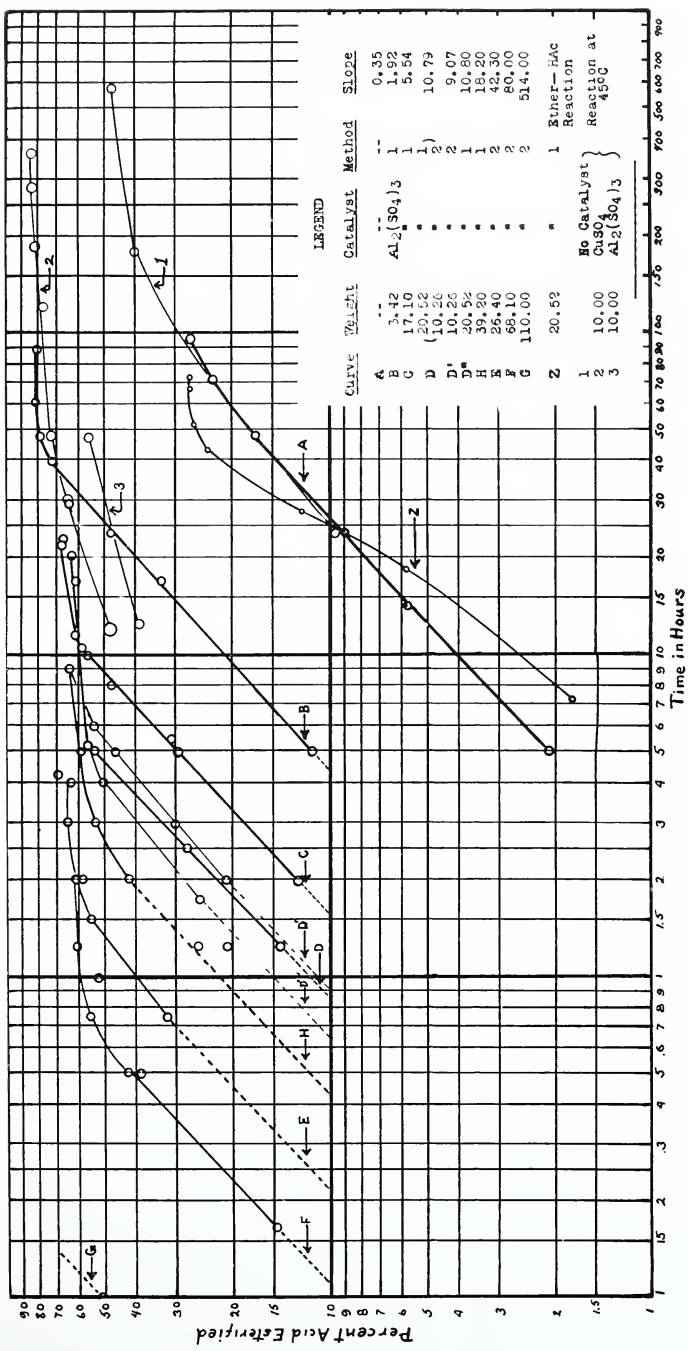
Percent Acid Esterified
Time in Hours
LEGEND
Curve | Weight | Catalyst | Method | Slope
A | -- | -- | -- | 0.35
B | 3.42 | Al2(SO4)3 | 1 | 1.92
C | 17.10 | " | 1 | 5.54
D | 20.52 | " | 1) | 10.79
D' | 10.26 | " | 2 |
D" | 10.26 | " | 2 | 9.07
H | 39.20 | " | 1 | 10.80
E | 26.40 | " | 1 | 18.20
F | 66.10 | " | 2 | 42.30
G | 110.00 | " | 2 | 80.00
Z | 20.52 | " | 2 | 514.00
Z | 20.52 | " | 1 | Ether—Hac Reaction
1 | 10.00 | No Catalyst | } | Reaction at 450°
2 | 10.00 | CuSO4 | |
3 | 10.00 | Al2(SO4)3 | |

Fig. 2.

Curve H shows the points after 17.1 g. of aluminum sulphate prepared by Method I were added to the 17.1 g. used in obtaining Curve C. We have taken the liberty of projecting the curve parallel to other lines of this series. The slope of the projected line between the 10% and 40% points is 18.2.

Curve D′ was obtained after the apparatus had been cleaned and refilled with 10.26 g. of aluminum sulphate prepared by Method II. The points indicated are the results of two consecutive runs. The slope of this line between the 10% and 40% points is 9.07.

The apparatus was cleaned again and Curve D″ was obtained with 20.52 g. of aluminum sulphate prepared by Method I. The slope of this line between the 10% and 40% points is 10.80.

The catalyst for Curve D″ was used to obtain the points on Curve Z for the reaction between diethyl ether and acetic acid. Curve D was obtained after 10.26 g. of aluminum sulphate prepared by Method II were added to this catalyst. The total weight of catalyst was 30.78 g. The slope of this line between the 10% and 40% points is 10.79.

The similarity of the results obtained with three distinctly different weights of catalyst shows that there was some influence of the method of preparation upon the rate of the reaction. Curve D indicates that the original two-thirds of the total catalyst used was very likely poisoned by the ethyl alcohol acetic acid reaction. That the 10.26 g. of added catalyst carried the burden of the reaction is supported by the similarity of the slope of D and D′.

Curve E shows the results obtained with 26.4 g. of new aluminum sulphate prepared by Method II. The slope of Curve E is 42.3.

Curve F presents the results of two runs after 41.7 g. of aluminum sulphate prepared by Method II had been added to the 26.4 g. used in Curve E, making a total of 68.1 g. The slope of this curve between the 10% and 40% points is 80.0.

Curve G is the result of one pass after the total weight of catalyst

TABLE II.

Curve	Weight	Catalyst	Method of Preparation	Slope
A	0.0	Glass Wool	.....	0.35
B	3.42	$Al_2(SO_4)_3$	1	1.92
C	17.1	"	1	5.54
H	34.2	"	1	18.20
D′	10.26	"	2	9.07
D″	20.52	"	1	10.80
D	30.78	"	1 and 2	10.79
E	26.4	"	2	42.30
F	68.1	"	2	80.00
G	110.0	"	2	514.00

had been increased to 110 g. by addition of aluminum sulphate prepared by Method II to that used in Curve F. The slope of this curve if projected parallel to other curves of this series is 514.0.

In Table II the weights of the catalyst are compared with the slopes of the respective curves. This slope represents the rate of the reaction in per cent conversion per hour. The letters accompanying the points refer to their respective curves in Figure 2.

No definite function of the rate of the conversion to the weight of the catalyst could be found. It was true however that where corresponding weights of the catalysts prepared by the two methods were compared, the velocity was greater with catalyst prepared by Method II.

Figure 3 shows the results obtained when similar runs were made on copper sulphate. The action was very erratic, and, since there was relatively little acceleration of the reaction, further discussion of copper sulphate has been omitted in this paper.

At the beginning of practically every run with aluminum sulphate a white fog appeared high in the condensers and persisted for about 15 minutes. On one occasion the water was removed from the condensers,

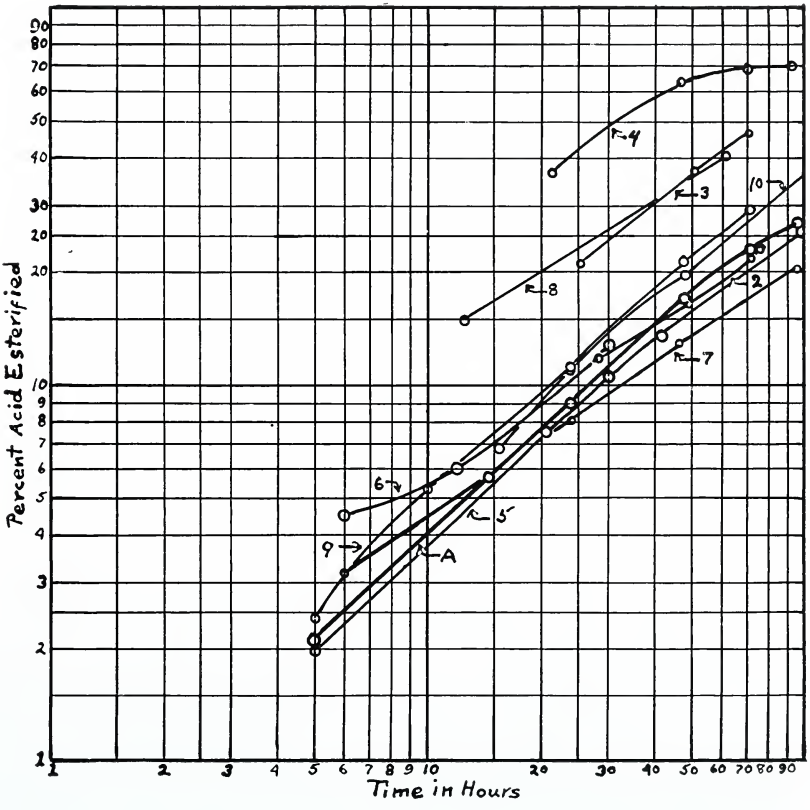

Fig. 3.

and this fog was allowed to rise over the top of the condensers. The odor indicated a fairly high concentration of ether. It was also noted that when the catalyst mass was flushed with alcohol for some time, a considerable quantity of ether was produced. On several occasions the ether appeared in sufficient quantities to be separated as a double layer when the contents of the apparatus were removed and diluted with water. It was decided that perhaps the ether might be an intermediate in the reaction between acetic acid and alcohol under these conditions. As a result, a few preliminary runs were made with ordinary stock ether and acetic acid. After some ethyl acetate was obtained in this manner, a complete run was made using 103.9 ml. absolute ether and 114.6 ml. of acetic acid. The data obtained from this reaction are presented by Curve Z, Figure 2.

Theoretical Discussion

The production of ethyl ether and the reaction between ethyl ether and acetic acid leads the authors to believe that the alcohol may be absorbed by the catalyst where it may react with other molecules of alcohol to form ether, with acetic acid to form ethyl acetate, or with itself and acetic acid simultaneously to produce ether and ethyl acetate. The suggestion of Adkins, Adkins and Nissen[8] that alcohol and ether are stable alike toward alumina at 350°C., 400°C., and 465°C. leads us to the further suggestion that in the course of the reaction between ethyl alcohol and acetic acid at 200°C., ethyl alcohol and the ethyl ether are both attached to the catalyst and react collectively with the acetic acid to form ethyl acetate.

Although we have made no precise attempts in the work reported here to obtain the location of the equilibrium point, the curves show that most of the points are between 60% and 70% of acid converted. The points outside of this range have been explained.

The data given here concerning the equilibrium point do not agree with Berthelot and St. Giles,[9] Edgar and Schuyler,[10] nor Milligan, Chapell, and Reid,[11] that the equilibrium point is far above that in the liquid state.

The reaction between ethyl ether and acetic acid is being studied at the present time and will be presented in a later paper.[12]

The theoretical kinetics of the reaction show that it should take place, and sizable yields of ethyl acetate have been prepared by the reaction. It has also been found that considerable dehydration of the ether to form ethylene takes place.

Conclusions

Ethyl alcohol and acetic acid were allowed to react in an apparatus designed to permit repeated passages of the reactants and the products through varied amounts of copper and aluminum sulphates. The following observations were made:

1. Copper sulphate did not produce results of sufficient importance to warrant extensive study.

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[8] Jour. Amer. Chem. Soc., 44:2175 (1922). Ibid 46:1301 (1924)
[9] loc. cit.
[10] Jour. Amer. Chem. Soc., 46:64 (1924).
[11] Jour. Phys. Chem. 28:872 (1924)
[12] Ruff and Whitacre. Unpublished Thesis. Case School of Applied Science, 1936.

2. Aluminum sulphate will dehydrate ethyl alcohol without the formation of appreciable amounts of decomposition products.

3. Aluminum sulphate will greatly increase the velocity of the reaction.

4. The method of preparing the aluminum sulphate affects the velocity of the reaction.

5. The average equilibrium percentage in all runs was 69% which agrees fairly well with the percentages found in liquid-phase esterification. These results are not in keeping with the predictions of Milligan, Chappel, and Reid.[13]

6. Ethyl ether and acetic acid were passed through aluminum sulphate with the formation of ethyl acetate. This leads the authors to believe that the gaseous reaction in the presence of aluminum sulphate may involve, under certain conditions, three reactions which run concurrently. These reactions are:

$$CH_3COOH + C_2H_5OH \rightarrow H_2O + CH_3COOC_2H_5$$
$$C_2H_5OH + C_2H_5OH \rightarrow H_2O + C_2H_5OC_2H_5$$
$$2CH_3COOH + C_2H_5OC_2H_5 \rightarrow H_2O + 2CH_3COOC_2H_5$$

If this be the case, the disagreement between the results of various investigators of vapor phase esterification may be explained on this basis.

[13]Jour. Phys. Chem. 28:872, 1924.

PROGRAM OF THE SECTION ON GEOLOGY AND GEOGRAPHY

Chairman: ALFRED H. MEYER, Valparaiso University

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1. Some phases of the limestone industry of Monroe County, Indiana. Barbara K. Dietrich, Indiana University.
2. Study of a mineralized area in the Harrodsburg limestone. Gordon F. Fix, Indiana University.
3. Auto-planetabling: An economical and expeditous method of geographic mapping. Alfred H. Meyer, Valparaiso University.
4. On a pre-Shelbyville extension of the Wisconsin ice-sheet. J. E. Ewers, Terre Haute.
5. Status of aerial photography in Indiana—October, 1936. T. M. Bushnell, Purdue University.

The following title was not included in the published program, but the paper is published in this volume.

Oölites in the Green River formation of central Utah, and the problem of oölite growth. Stewart L. Schoff, DePauw University.

Dr. Wendell LeRoy Perkins, of Indiana State Teachers College, was elected chairman of the section for 1937.

Indiana Regional Contrasts in Soil Erosion and Their Chief Causes

Stephen S. Visher, Indiana University

Introduction.—*The Problem:* How great are the regional contrasts in Indiana with respect to soil erosion? What influences have caused the contrasts? What is the relative significance of each of the more important factors? *The Method:* An analysis has been made of the map of soil erosion issued in 1935 by the Soil Conservation Service, and some of the findings are shown on ten maps reproduced here. Maps of several factors suspected of helping to cause erosional contrasts were made and compared with the erosion maps. *Conclusions:* There are very notable regional contrasts in soil erosion in Indiana. Some of these are correlated with contrasts in local relief, others with the soil types, others with the recency of glaciation, and others with land use. Regional contrasts in rainfall intensity, a factor hitherto not discussed as important, appear to be of notable significance in causing part of the observed contrasts. (A more detailed summary closes this paper.)

Although very little of Indiana has been cultivated for as much as a century, nearly half of the state has suffered extensively from soil erosion. This has happened as a result of the type of agriculture that has prevailed, the relatively large amounts of rainfall received during the cooler months, and the fact that at least half of the state has sufficient slope to permit fairly rapid runoff whenever there is considerable rainfall.

As Indiana is representative of a considerable area in the midwest, the Soil Conservation Service of the United States Department of Agriculture has deemed it worth while to make a special study of the soil erosion in this state. The present writer (formerly a Scientist in the U. S. Bureau of Soils) spent the past summer upon a study of the regional contrasts in erosion in Indiana, with special attention to the factors that caused the contrasts. This study had two phases: first, field work in all of the counties; and, second, an analysis of the map showing the amount of erosion, and of data of various sorts that might help explain the contrasts. The report, when completed, will treat in considerable detail of various factors.

In the present paper, there is space for only a brief analysis, largely by means of maps, of the erosional contrasts and of some factors that have contributed to cause the contrasts.

First, a few statements concerning the state as a whole: About 43% of Indiana has suffered considerable erosion, having lost more than one-fourth of its original topsoil, on the average. Three great types of erosion are extensive, namely sheet erosion, gullying, and wind erosion. Sheet erosion is more widespread than gullying, as about 40% of the state has suffered rather serious damage from sheet erosion in contrast to about 31% which has been somewhat gullied. As all the gullied areas are also subject to sheet erosion, the 31% of the state that is gullied is included in the 40% where sheet erosion is considerable. Wind erosion

is also of local significance, and some 650,000 acres, or nearly 3% of the state, have been damaged by wind erosion.

The extent of erosion damage: From one-fourth to three-fourths of the original thickness of the topsoil has been widely removed[1] by sheet erosion in one-third of the state; from an additional 7% of the state, more than three-fourths of the topsoil is generally gone. A fifth of the state has what the Soil Conservation Service officially classes "occasional" gullies, and one-ninth has "frequent" gullies, or severe gullying. Wind erosion has seriously damaged some 30,000 acres.

An Analysis of the Erosion Data

The statements of the amount and kind of erosion here given are based on a study of the reconnaissance erosion survey map of Indiana recently issued by the Soil Conservation Service. This large map is quite complicated. Planimeter measurements have now been made of the areas of each type of erosion mapped. The percentages that each erosion type makes up of the total area of each county have also been calculated, and are used as the basis for several of the following maps. The analysis of erosional contrasts may appropriately commence with

Fig. 1. Erosion map. Unshaded areas have in general little or no serious erosion as compared with the shaded areas. (Adapted from the map of the Soil Erosion Survey by the Soil Conservation Service.)

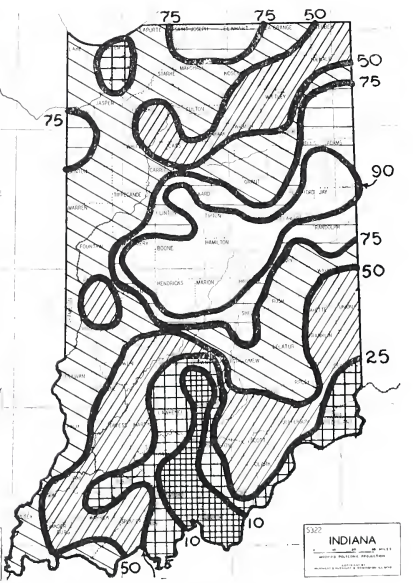


Fig. 2. Percentage of each county having little or no serious soil erosion. (Based on planimeter measurements of the large map just mentioned.)

[1]A square mile is classified as of a given erosion type if as much as 25% of its area belongs to that erosion type. The above statements do not mean, for example, that a large share of all the topsoil has been removed from every acre of one-third of the state but, instead, that in one-third of the area of the state this type of erosion prevails on at least one-fourth of each square mile.

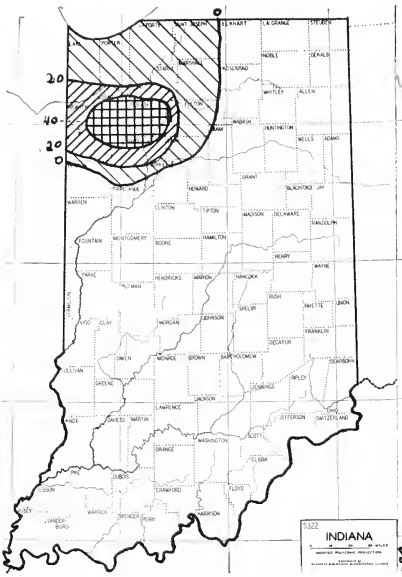


Fig. 3. Wind erosion. Percentage of each county where considerable areas are damaged.

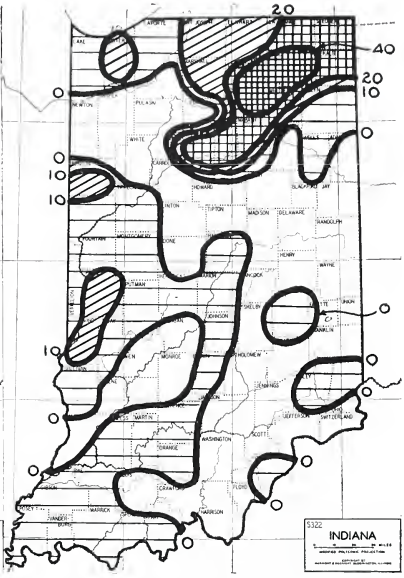


Fig. 4. Sheet erosion without gullying. Percentage of each county in which this type prevails.

the distribution and relative extent of the areas upon which there has been, in general, little serious soil erosion. Figure 1, adapted from the soil erosion survey map just mentioned, shows two types of area. Those left unshaded have suffered little erosion as compared with the shaded areas, which have considerable erosion. (Some of the unshaded areas along the rivers in the southern half of the state are somewhat too wide; likewise within the shaded and unshaded areas there are small areas of the opposite type, too small to be shown on this scale.) This map indicates that most of the extensively eroded land is in the southwestern third of the state, in parts of the southeast, and in various wide bands in the north. Conversely, the areas that are little eroded are largely in the central part of the state.

Figure 2 shows the percentage of the area of each county which was classed as subject to little erosion. This map indicates some of the sharp regional contrasts more effectively than does Map 1. The chief areas in which less than one-quarter of the land is classed as being notably eroded are in central and northern Indiana. The percentages for various counties, not given on the map since they would be scarcely legible at the scale used, may be mentioned: Tipton and Boone 100%, Blackford 98, Madison 97, Marion 96, Hendricks and Montgomery 93, Carroll 92, Jay and Wells 89, Adams 88, Randolph 86, Shelby 84, Howard 83, Allen 82. Conversely, counties with small percentages of uneroded land are Crawford 0.6%, Orange 5, Harrison 6, Brown 8, Pike 11.

Figure 3 shows the percentage of the area which has suffered appreciably from wind erosion. Although some small sandy areas in

Jackson County and in the southwest (Knox and Gibson counties) have suffered from wind erosion, the only counties that have had as much as 1% of their area damaged by wind erosion are near the northwestern corner of the state. There, 44% of Pulaski County, 43% of Jasper, 28 of White, 23 of Newton, 19 of Lake, 11 of Marshall, and from 1% to 6% of five adjacent counties have been notably damaged by wind erosion.

Figure 4 treats of sheet erosion which is not accompanied by appreciable gullying. This map shows that in the northeastern counties from 10 to 40% of the area has generally lost one-fourth or more of its original topsoil by sheet erosion without gullying. Except in two small areas, one in the northwest and the other in the west-central parts of the state, no other counties have simple sheet erosion upon as much at 10% of their area; indeed most counties have less than 1% of their land eroded in that way.

Figure 5 shows sheet erosion accompanied by gullying as well as that without gullying. It has a very different appearance from Figure 4, because most sheet erosion is accompanied by gullying. This map shows that half or more of the area of each of the southern counties has suffered considerable ("moderate" or "severe") sheet erosion, and that 75% or more of several south-central counties have so suffered. Crawford County is almost all (99%) subject to considerable sheet erosion. Other high counties, with the percentage of their area classed as having considerable sheet erosion on a large part of each square mile, are Orange 98, Brown 92, Pike 87, Dearborn 82, Lawrence and

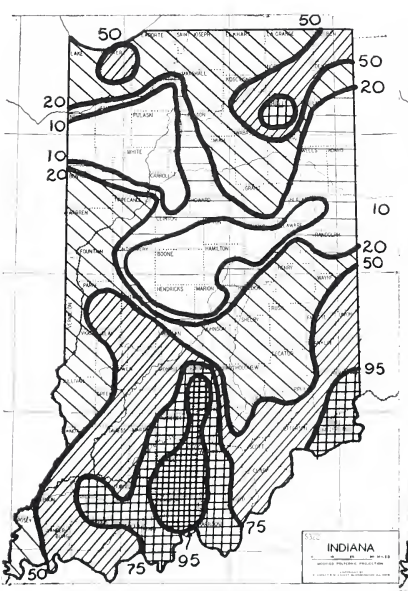


Fig. 5. Sheet erosion without or with gullying. Percentage of each county distinctly affected.

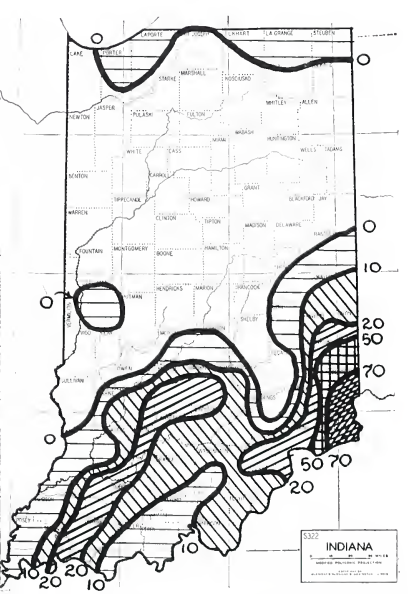


Fig. 6. Severe sheet erosion. The relative abundance of this type of soil loss.

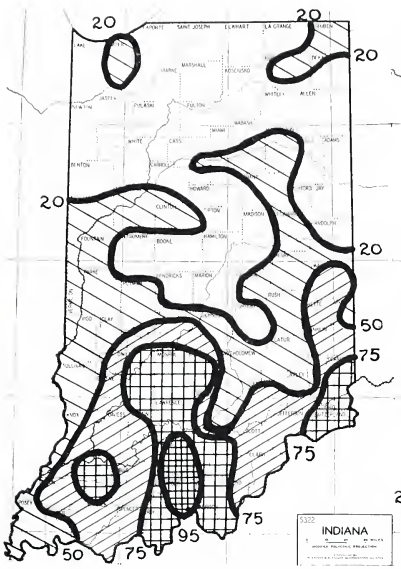


Fig. 7. Gullying. The percentage of each county affected by gullying.

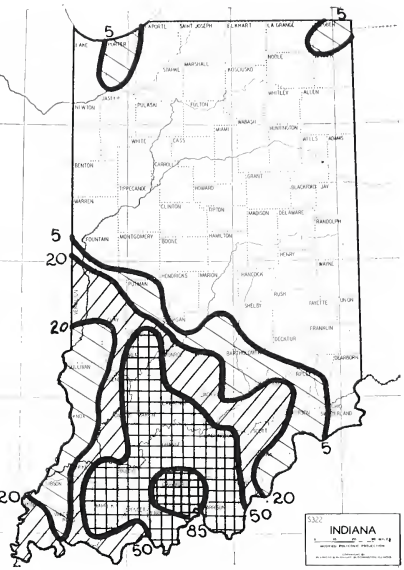


Fig. 8. Frequent gullies. The relative proportion of land cut by frequent gullies.

Switzerland 79, Perry and Ohio 78, Harrison 77, Washington 76, Owen 74, Monroe 73, Floyd and Noble 72, and Martin and Clark 71.

Figure 6, which illustrates severe sheet erosion (three-fourths or more of the original topsoil gone) reveals that this type of erosion is almost confined to the southeastern third of the state, together with four counties on the Michigan border. Severe sheet erosion is worst at the southeast corner, where 77% of Dearborn County, 76% of Ohio, 69% of Switzerland, and 58% of Franklin are classed as of this erosion type. However, further west are five counties in this same category: Dubois with 52%, Scott 42, Vanderburg 34, Martin and Brown 20.

Gullying

Figure 7 concerns the distribution of gullies. Gullying is very widespread; only four counties were mapped by the erosion survey as lacking sizeable areas that were gullied. These were Tipton, Boone, Newton, and Jasper. Counties with only about 1% of their land somewhat gullied are Pulaski, White and Marion. Other fortunate counties in this respect, with their percentages, are Blackford 2, Madison 3, Hendricks and Montgomery 4, Starke 6, Marshall 7, Carroll 8, and the following 9 each: Benton, Hamilton, Kosciusko, Lagrange, Wells. By contrast, most of the counties of the southern half of the state have 40% or more of their land somewhat gullied. The least fortunate counties in this respect, with the percentages of their areas of this type, are Crawford 99, Orange 96, Brown 92, Pike 86, Dearborn 81, Switzerland and Lawrence 79, Harrison 78, Washington and Ohio 77, Monroe 76, Perry 75, and Owen 74.

Two types of gullying were distinguished by the erosion survey, namely "occasional" and "frequent" gullies. The percentage of the land with occasional gullies is greatest at the extreme southeast, where nine counties have more than half of their land in this type. These extend from Wayne to Clark counties. Switzerland, Ohio, and Dearborn counties each have 77 to 79% of their land of this type. The only other counties with half or more of their land classed as eroded by occasional gullies are Brown 66, Orange 55 and Gibson 50.

Figure 8 shows the percentage of the area classed as having frequent gullies. This map reveals that severe gullying is largely confined to the southwestern third of the state. Ten counties near the center of that section have more than half of their land of this type. Crawford County has 89% of its area of this type, frequent gullies on a large share of each square mile. On the other hand, more than half of the counties of the state have no considerable tracts of badly gullied land. The counties reported by the erosion survey as having small areas of this type may advantageously be listed, since by so doing, the counties which have no appreciable area of this type are indicated indirectly, namely the remaining counties of the area shown on Map 8, as having less than 5% of their area with frequent gullies. Counties with about 4% of this type are Cass, Wayne, and Dearborn; with 3%, Huntington, Montgomery, and Laporte; with 2%, Lagrange; and with some areas, but less than 1.5%, Elkhart, Noble, White, Carroll, Wabash, Fountain, Henry, and Sullivan.

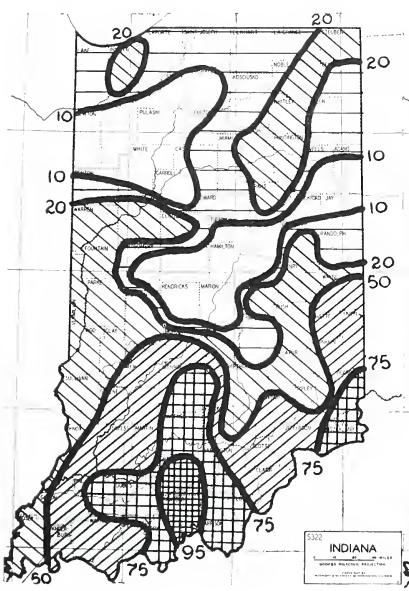


Fig. 9. Considerable sheet erosion and gullying. The percentage of each county in which these two types of soil destruction prevail.

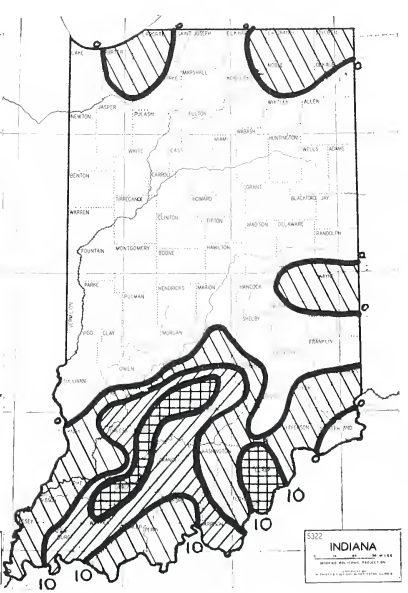


Fig. 10. Frequent gullies and severe sheet erosion. The relative proportion of the land being destroyed by these types of erosion. Correction: the elongate, double crossed area is 20+; the smaller one is 10 to 20.

Since gullying and sheet erosion generally occur simultaneously, on the same land, Figure 9, showing the percentage of each county having considerable of both erosion types, is of special interest. These percentages of their areas have in general lost more than one-fourth of their original topsoil by sheet erosion, and also have occasional or frequent gullies. This map shows that more than half of the area of most of the southern counties is of this type. Some ten south-central and three southeastern counties have over 75% of their areas in this category, and near the center of the south-central area, Crawford and Orange counties have 99% and 95%, respectively.

Maps of the various combinations of sheet erosion and gullying have been made, but there is not space here to reproduce all of them. Three may, however, be briefly described. The counties with the largest percentages of their areas damaged by moderate sheet erosion and occasional gullies, with the percentage of their area thus affected are Brown 66, Orange 65, Clark 55, Morgan 54, Gibson 50, Jefferson 49, Knox 45, Henry 41, Warren 40, Fayette and Wayne 39, Clay 35, Decatur and Monroe 34, Sullivan 33, Union and Tippecanoe 32, Grant 31, and Jennings and Delaware 28. Most of these high counties are in the southwestern third of the state. The largest area with little erosion of this particular type is in the northwestern part of the state and the next largest is in the center of the state.

Moderate sheet erosion is accompanied with frequent gullies in much of the southwestern part of the state, where some 12 counties extending from Parke to Floyd and Warrick have 30% or more of their areas of this type and four counties have more than half of their areas thus classified. By contrast, only three counties to the north or east of a line from Jefferson to Fountain counties have as much as 1% of their land in this category. They are Porter 40, Steuben 7, Cass 5, and Huntington 3.

Severe sheet erosion and occasional gullies damage most land at the extreme southeast, where four counties have over half of their land in this category, namely, Ohio 76, Dearborn 73, Switzerland 69, and Franklin 58. Nearby counties also rank relatively high, Fayette 21, Union 10, Wayne 11, Ripley 4, and Rush 2. In no other part of the state is this combination extensive except in Vanderburg County 21%, Lawrence 5, Harrison 4, Washington 3, and Morgan and Johnson 2. None of the counties of the northern half of the state have as much as 1% of this type.

The final map of erosion is that showing the most serious combination, that of numerous or frequent gullies and severe sheet erosion. In this type, less than one-fourth of the original thickness of the topsoil remains, and in many places the topsoil is all gone. Likewise gullies are numerous, a considerable number of them cutting well into the subsoil, or even down to the bed-rock. This most extreme type of widespread erosion in Indiana is dealt with in Figure 10. It is largely confined to the southern third of the state and affects the largest percentage of the land in the counties extending from Brown to Pike, which have from 20 to 52% of their land of this category. Various nearby counties also rank high. North of the line marked O in Figure 10, there are, however,

only nine counties, with appreciable representation of this type, severe sheet erosion and frequent gullies. They, with the percents of their areas, are Wayne 5, Steuben and Laporte 3, Porter and Lagrange 2, Noble and Henry 1, and Parke and Elkhart with less than 1%.

A Summary for Erosion. A brief summary of the results of the above analysis of soil erosion in Indiana is desirable before considering the probable explanations of the regional contrasts disclosed.

Except for wind erosion which is most extensive in the northwest, erosion is most extensive in the southern part of the state. Indeed much of the central and north-central part of the state has little serious erosion. In the extreme northern and northwestern counties, moderate sheet erosion without gullying is, to be sure, rather extensive in the rougher counties. Nevertheless, severe sheet erosion is largely confined to the counties near the Ohio River. In general, gullying likewise increases in severity southward, although it is by no means lacking on the steeper slopes in the north. Gullies are most numerous, on the average, in the south-central and southwestern parts of the state, although on some of the almost flat land near the rivers they are not numerous.

The combination of considerable (moderate or severe) sheet erosion with considerable gullying (occasional or numerous gullies), dealt with in Figure 9, shows quite clearly the general southward increase shown by most of the maps. But this combination is of such significance that it has been analyzed in a special way. The counties north of latitude 41° have on the average about one-eighth of their area subject to considerable erosion of these types. The belt between the 40th and the 41st parallels (22 counties) have an average of about one-sixth of their area of this category. The 25 counties between the 39th and the 40th parallels have an average of 43% of their areas in this same category. The 24 counties south of the 39th parallel have, on the other hand, an average of 66% of their areas in this category.

Some Possible Explanations of the Regional Contrasts in Erosion

Why this southward increase? Why the greater erosion in the central section of southern Indiana than on either side? Why the more intense erosion at the extreme southeast corner? Why more gullying at the southwest than in the southeast or even in the south-central section?

The regional contrasts in soil erosion must necessarily correlate with variations in the effectiveness of the agencies of erosion, which here are the wind and running water, and with the availability of soil materials that can be carried away by these agents. The effectiveness of the wind varies with its strength, with the dryness and looseness of the soil, and with the protection afforded by vegetation or other barriers to wind movement. In Indiana, wind erosion is largely confined to the sandier soils, which are the only ones that normally are loose when dry. The loams and clays commonly are quite hard when dry. Even when pulverized by cultivation, clays and loams very seldom remain loose on top for more than a short time in Indiana. This is because showers are frequent enough here, especially in spring when most cultivation is done, soon to form a crust on top of the loosened layer of clay or loam. Sand,

however, lacks the stickiness required to form such a crust, and soon after a shower it may be loose enough to be moved by the wind. The sandy soils in all parts of the state are not equally eroded by the wind. Sandy soils in southern Indiana, in Jackson and Gibson counties, for example, are eroded less than are similar soils in the northwest, partly because they are less dry in winter. The northwestern corner of the state receives less precipitation in the winter than any other part, less than two-thirds as much as southern Indiana, and also has the strongest winds then. These conditions are highly favorable to wind erosion, as are the extensive sandy areas, the small interference from trees or hills, and the extensive corn fields, many of which are rather barren in winter.

Most erosion in Indiana is accomplished by the run-off of rain. The greater the run-off, the greater the potential erosion, both because of the greater volume of water to do the work, and especially because of the greatly increased velocity that the run-off attains as the amount increases. When there is little run-off, the friction with the surface and small obstacles normally permits only a slow flow, which means little transporting power and hence little erosion.

The amount of run-off varies with six main factors: the amount of rainfall, its intensity or rate of fall, the slope, the amount of absorption by the soil and associated materials, the evaporation, and the vegetal cover. The slope includes not only the larger features, but also the lesser irregularities and the presence of channels. The amount of absorption depends upon the porosity of the soil itself, the openings in the soil, such as root cavities and the burrows of animals, and, especially, the degree of saturation. Even a sand, which can absorb one-fourth of its weight of water when dry, cannot absorb much water if its upper layers are already saturated.

Annual and seasonal rainfall: In Indiana the amount of rainfall varies for the annual average from slightly less than 35 inches at the north to about 45 inches at the south. Hence, if all other factors were equal, the amount of erosion should be approximately one-third greater at the south than in the north. But instead of being one-third greater, it is several times as great! (A map of the annual precipitation is given in the *Proceedings* for last year, Fig. 20, p. 193.)

The rainfall during the four warmer months, June to September, inclusive, causes far less erosion on the average than do similar amounts during the cooler months. This is because in the summer the soil is commonly dry enough to absorb a considerable share or all of the rainfall if it does not fall with too great intensity. Moreover, evaporation is relatively rapid, soon removing a part of the water. Furthermore, the soil is more porous in summer than during the rest of the year because of the greater activity of burrowing animals and man (cultivation). Finally, of especial importance, vegetal protection normally is greatest in those months.

Hence, the regional contrasts in the amount of rainfall during the cooler months is much more significant as far as erosion is concerned than is the annual total. In Indiana all parts receive about the same amounts of rainfall during the summer, and, as a result, the contrast in winter is notably greater than for the year as a whole. During the

eight cooler months the totals in the north average about 21 inches, in the center about 25 and at the south about 30 inches. Figure 11 shows the "standard" precipitation totals for these months for the various parts of the state. (The "standard data" are the figures for the 35-year period 1898-1932 and are more strictly comparable than are the averages of all data.) This map reveals that southern Indiana receives nearly a half more precipitation during the cooler months than does the north. Indeed, several stations in south-central Indiana receive approximately 32 inches of rain in these months, which is 60% more than the total for three northwestern and two northeastern stations.

During the three winter months, the contrast is even greater, because of the scanty precipitation received then at the north. In the three winter months, the southern counties receive nearly twice as much precipitation as does the north, and Crawford County and vicinity more than twice as much as the northwestern or northeastern corners of the state. (A map of the winter precipitation forms Fig. 26, p. 198, of last year's *Proceedings*.)

Hence, the regional contrasts in the amounts of rainfall received annually, and especially during the cooler months, help explain the regional contrasts in erosion. But the erosional contrasts are much greater than the contrasts in mere annual or seasonal rainfall, and, hence, other factors merit consideration.

Glacial Contrasts and Erosion. Southern Indiana differs from northern Indiana with respect to glaciation. Figure 12 is a glacial map, simplified from Malott's map (1922), which in turn was based on Lever-

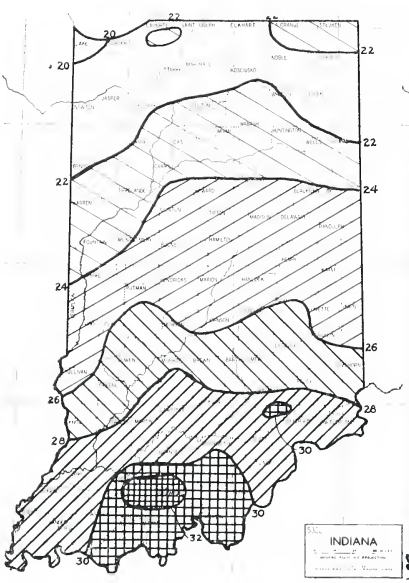


Fig. 11. Percipitation during the eight cooler months, October to May inclusive, in inches.

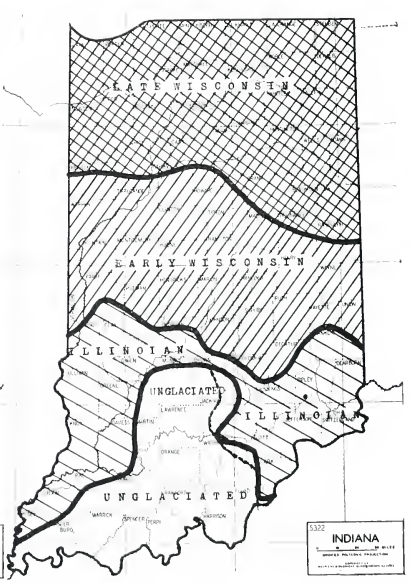


Fig. 12. Glaciation areas (after Leverett and Malott).

ett's map (1914).[1] When this map is compared with the erosion maps, it is apparent that there are general correlations between glaciation and erosion. Thus, the unglaciated area has in general more erosion than the glaciated, and the areas covered by the older, Illinoian glacier, have more erosion than the section covered by the Wisconsin ice sheet. Similarly the area covered by the Late Wisconsin advance has, on the average, less water erosion than does the Early Wisconsin drift sheet. Such contrasts are to be expected, as erosion requires time, and sufficient time has not yet elapsed since the Late Wisconsin to drain adequately many parts of northern Indiana. Run-off erosion is necessarily slow when there are no appreciable slopes or channels. On the other hand, the region covered only by the Illinois ice sheet has been rather thoroughly drained and reduced to slopes. Most of the unglaciated area is rather hilly.

The contrasts in glaciation are, however, inadequate to explain nearly all the contrasts in soil erosion. Moreover, the question as to what caused the glaciers to terminate where they did is a proper one to raise in this connection. Quite probably their extent is merely a reflection of more fundamental conditions which affect erosion independently.

The inadequacy of the distribution of glaciation to explain the contrasts in erosion may be briefly illustrated. Although both the southeastern and southwestern parts of the state were covered by the Illinoian ice sheet, they differ quite decidedly in erosion; the percentages of the areas with severe sheet erosion are greater at the east, while gullying is more widespread and severe at the west. Likewise, although the unglaciated area has more erosion on the average than the Illinoian area, nevertheless parts of the latter are about as unfortunate. Moreover, parts of the unglaciated area are classed as subject to little or no erosion, while certain areas of even the Late Wisconsin drift sheet are rather badly eroded.

Slope: Another factor of major significance, unquestionably, is the amount of slope of the land. Figures 13 and 14 deal with local relief in two ways. Figure 13 deals with the maximum local differences in elevation for each county, while Figure 14 classifies the various parts of the state into four categories of ruggedness. The data upon which both these maps were based are rather unsatisfactory, as topographic maps of only a small portion of Indiana have been made. Figure 13 is based on data compiled by Malott in his chapter on Physiography in the *Handbook of Indiana Geology*, 1922. Figure 14 is based on miscellaneous field impressions. The part of the state shown as cross shaded is, in general, rather hilly; the area which is shaded most lightly is, in general, level or almost level. The other two types are intermediate, the darker one the rougher.

Local relief clearly helps explain some of the erosional contrasts, such as a part of the considerable contrast between the southeastern and

[1]In the area here labelled as unglaciated, that part east of the dashed line is not entirely lacking in glacial deposits, although most of it is rugged upland, resembling the unglaciated area to the west rather than the more strongly glaciated area to the east. See W. D. Thornbury, Notes on the glacial boundary in southern Indiana. Proceed. Ind. Acad. Sci. 41:351-354, 1932.

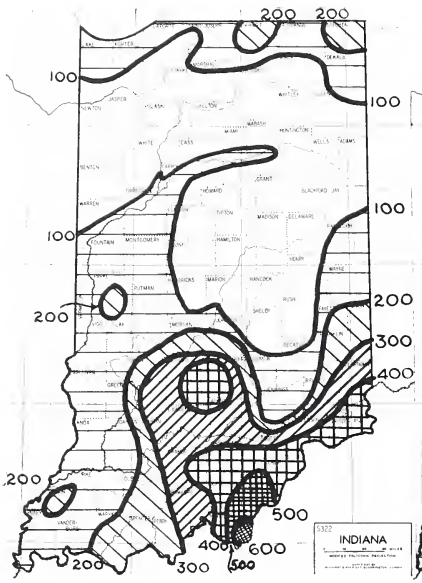


Fig. 13. Contrasts in maximum local relief, by counties.

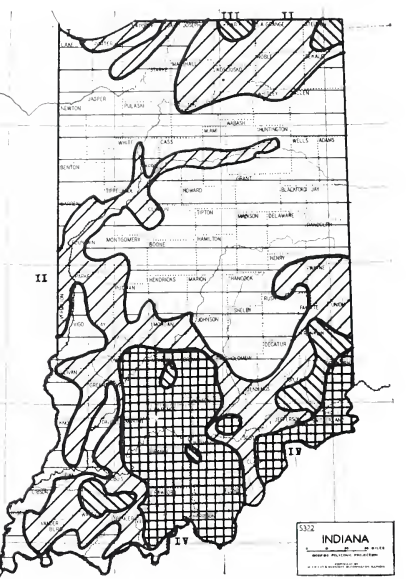


Fig. 14. Regions as to ruggedness. The crossed areas are prevailingly hilly; those with the lightest shading are prevailingly almost level.

the southwestern corners of the state, both covered by the Illinoian ice sheet, but now differing markedly in local relief. The greater local relief also helps to explain the presence of extensive erosion in the area from Parke to Owen County although it was covered by the Illinoian ice sheet. Likewise the greater erosion in some of the most northern counties, especially at the northeast, as compared with adjacent counties to the south, is obviously related to their greater relief, due to terminal moraines.

The relief features of Indiana are of four main sorts: those due to the irregularities of glacial deposition (over much of the northern half of the state); those due to wind work (the sand dunes near Lake Michigan); those due to solution (the sinkhole topography of part of the unglaciated region); and, finally, those due to run-off. The topographic irregularities due to run-off erosion doubtless checked glacial advance. Two other influences interfering with the extension of glaciation were elevation and unfavorable climate. The northeastern part of the unglaciated area is relatively elevated (a map showing elevations may be found in Proceedings for last year, Fig. 2, p. 185). These areas are less elevated, however, than is an extensive glaciated area nearby. Moreover, a considerable southwestern part of the unglaciated area is the least elevated part of the state, or only a little higher. Hence climatic conditions and local relief seem to have been more important than local elevation in determining the termination of the glacial advance. (Distant differences of elevation helped in the development of glacial lobes, which were a great factor in determining the relative advance of the ice-front.)

It has commonly been assumed that the aspect of the climate which was of overwhelming significance in stopping glacial advance was the temperature. Southern Indiana has, to be sure, higher average temperatures than central or northern Indiana, but the differences are slight during the summer months. Indeed, continental interiors generally warm up in summer so greatly that the decline in temperature with increased latitude is relatively small.

A climatic factor of great significance in melting the ice is rainfall. If rainfall is abundant in the winter as well as in the summer the glacier advances with greater difficulty if at all. Moreover, abundant cool season rain is, as already remarked, especially effective in causing run-off erosion, and, hence, in making the topography rugged, which ruggedness likewise interferes seriously with glacial advance.

The much greater rainfall during the cooler months in southern Indiana than in northern has already been mentioned and mapped (Fig. 11). Here, however, attention may advantageously be devoted for a time to the regional contrasts in rainfall intensity.

Rainfall Intensity and Erosion: Figures 15 to 20 deal with various aspects of rainfall intensity. Figure 15 shows the frequency of months during which a total rainfall of ten inches or more falls during the month. It reveals that such a large monthly rain occurs at least once a year in more than one-tenth of the cooler half-years at the southwest but almost never in most of the northern part of the state. The area where erosion is most intense (Fig. 10) roughly coincides with the area that has ten inches of monthly rainfall most frequently.

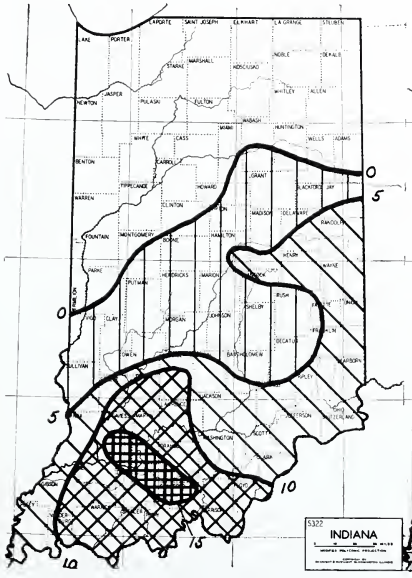


Fig. 15. Ten inches of rain in a month. Percentage of the cooler half years having such a monthly total.

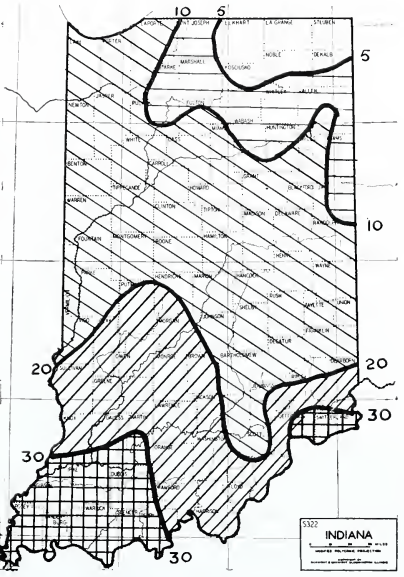


Fig. 16. Two-day rains of six inches or more. Percentage of years with such.

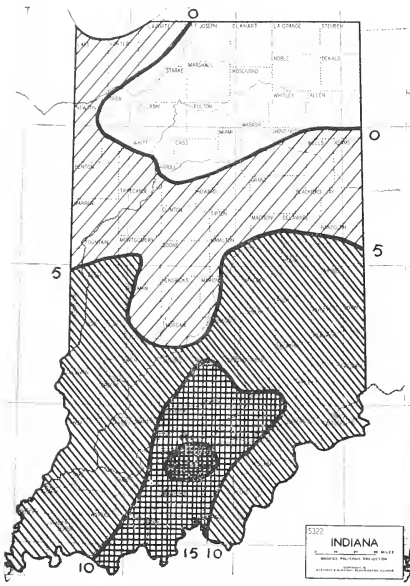


Fig 17. Four-day rains of six inches or more. Percentage of years with such.

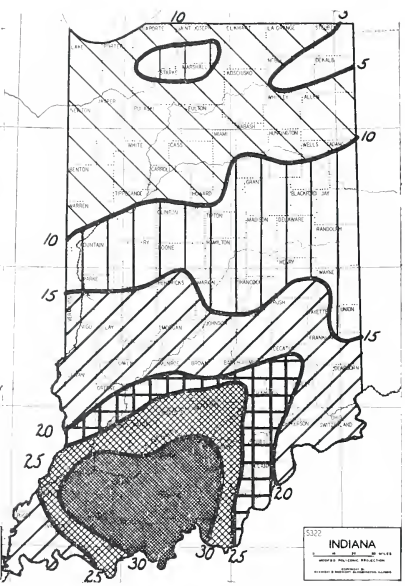


Fig. 18. Daily rains of one inch or more, in winter. Times per decade.

Figure 16 concerns the frequency of two-day rains of four inches or more. It indicates that the southwestern corner of the state receives four inches of rain during two consecutive days at least once a year in more than 30% of the years. By contrast, such rains occur less than one-sixth as often at the opposite corner of the state.

Figure 17 deals with even greater rainfall totals, those of six inches or more falling within four consecutive days. Such a prolonged heavy rain necessarily results in much run-off and extensive erosion if other conditions are favorable for erosion. This map shows that in south-central Indiana from 10 to 15% of the years have such rains, while a large area in the north has scarcely ever experienced such rainfalls.

Figure 18 deals with a much more common type of rain, daily rains of one inch or more. It shows that during the three winter months such rains are received in the southwest-central part of the state more than three times an average winter. On the other hand such rains are less than one-third as common in most of northern Indiana, and less than one-sixth as common in northeastern Indiana.

Figure 19 deals with the frequency of two-day rains of two inches or more in winter. A large share of such rainfall must necessarily run away as the ground normally is saturated by the first inch of winter rainfall, if not before. This map shows that two-day rains are several to many times as frequent in southern Indiana in winter as in most of northern Indiana. Indeed, in about one-sixth of the state, in the north, such rains occur less than once a decade on the average, in contrast with more than ten times at the southwest.

Consideration has now been given to annual, seasonal, and monthly rainfalls, and to the rainfalls during one day, two days, and four days. Another type of rainfall which is highly significant so far as soil erosion is concerned, is the "short rain of excessive amount." When an inch of rain falls during one hour, or an inch and a half within two hours, for example, the run-off normally is great from sloping land as there is not time enough for much rain to soak into the ground. Such rains during the cooler season are especially conducive to soil erosion because the soil normally is already fairly well saturated before the deluge commences. Figure 20 shows that excessive short rains are almost unknown in winter in northern Indiana but occur in about one-fourth of the winters in the southwest. (The figures are times per 30 years.)

The striking regional contrasts in rainfall intensity that occur in Indiana, illustrated by Figures 15 to 20,[2] clearly are helpful in explaining the observed regional contrasts in erosion. Since these contrasts are largely due to fundamental conditions, it is altogether probable that similar contrasts existed during the glacial period and before. (Regional contrasts in the duration of snow-covered and of frozen ground also help explain the relatively greater erosion in southern than in northern Indiana. These influences and others are discussed in a more technical paper.)

In addition to the broad regional contrasts in soil erosion discussed above, there are many local contrasts associated with differences in soil, vegetation and farm practices. Some of them have regional aspects.

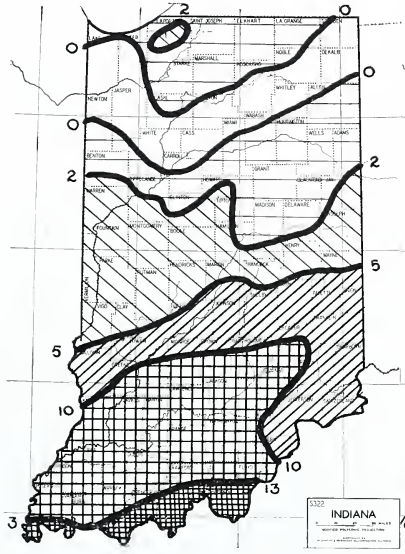


Fig. 19. Two day rains of two inches or more, in winter. Times per decade.

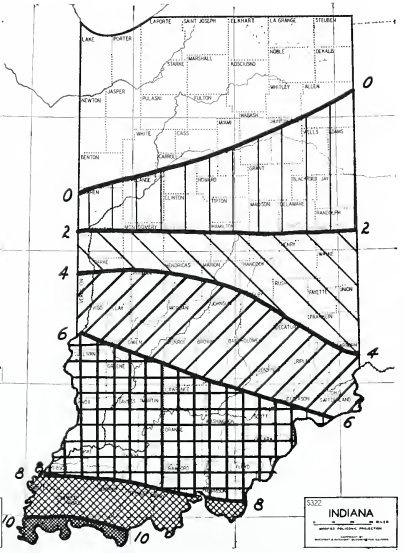


Fig. 20. Number of excessive "short rains" (one inch per hour or 1.5 inches in two hours) per thirty winters.

[2]Figure 20 is based on all the available records at five regular weather bureau stations in Indiana, supplemented by the data gathered by five nearby regular stations, Chicago, Louisville, Cincinnati, Dayton, and Peoria. Figures 11, 15, 16, and 17 are based on all the available data accumulated from eighty Indiana stations. Figures 18 and 19 are based on the daily records for one recent decade for all Indiana's stations.

For example, since southern Indiana was settled before northern Indiana, clearing was done sooner, and soil erosion of tilled land commenced earlier. During the past 40 years, however, many of the steeper slopes in southern Indiana have been abandoned because so much of their soil had been removed during the period of cultivation. (In some parts of southern Indiana, certain hillsides are classed as "ten-year land" because during ten years of tillage by the customary methods so much of the soil washes away that further tillage is unprofitable.) As a result of the abandonment, some time ago, of many areas in southern Indiana, the average period of cultivation in southern Indiana is perhaps no longer than that of northern Indiana despite the fact that much of northern half of the state was not cleared until two or three decades after the south was well settled.

The large proportion of the more rugged parts of southern Indiana that are now covered with brush or trees led to an interesting and significant "inaccuracy" in the soil erosion map. Since wooded areas lose soil by erosion only slowly, wooded tracts are classed as subject to little erosion if they are not gullied. If they are gullied, they are generally classed as subject to moderate erosion. If wooded tracts make up more than 75% of the land of any square mile, the surveyors were required by their instructions to report the land as subject to little or moderate erosion, even if rapid erosion prevailed on the small percentage of cultivated land. (Several southern counties had at the 1935 agricultural census only relatively small percentages of their areas in harvested crops. Examples, with the percentages are: Brown 10, Crawford, Martin and Monroe 19, Perry 20, Lawrence and Orange 22, Harrison 23, Washington and Scott 24, Jefferson 26. The state average is 44, with Benton County 68. As a result of these instructions as to how to classify the land, the soil erosion map analyzed in Figures 2-10 underestimates the regional contrasts in erosion.

Conclusions

There are marked regional contrasts in soil erosion in Indiana. Upon moderate slopes on comparable soils, erosion is several times as rapid at the south as at the north; upon steep slopes, the differences are even greater. These contrasts are associated with contrasts in rainfall since run-off is the one great cause of soil erosion in Indiana, except on some very sandy tracts especially in the northwest where wind erosion is significant. The one-third greater annual rainfall which the south receives helps to explain the contrasts in erosion, but the fact that the south receives nearly one-half more rainfall during the cooler eight months than does the north is even more significant, as a larger percentage of cool-weather rain runs away. Differences in the length of time since the glaciers covered the various parts of the state are also of significance, as the development of drainage run-off courses and related slopes required much time when the state was forested, as it nearly all was until about a century ago. The amount of local relief, a special phase of the slope, is of further assistance in causing the observed regional contrasts in soil erosion. A climatic factor not previously investigated, namely regional contrasts in rainfall intensity, is

also clearly of great importance in causing the large regional contrasts. Southern Indiana has several to many times as many downpours and consecutive days of heavy rain, as does northern Indiana. Such rains yield much mode run-off than do moderate ones, and since the transporting power of run-off increases approximately as the cube of the velocity, erosion increases enormously where heavy rains occur relatively frequently, provided the soil is not protected by adequate vegetal cover. The evidence presented here should hasten the program of reforestation of all the steeper slopes in southern Indiana.

Epilogue.—The considerable amount of soil loss that has resulted in Indiana in only a century or less from the cultivation of sloping lands makes very desirable certain changes in the use of such lands. The demonstrations conducted by the Soil Conservation Service in Lawrence and Henry counties and elsewhere show methods by which moderate slopes can be farmed with much less soil wastage than has occurred with the prevailing practices. These demonstrations and others have also disclosed approximately what amount of slope, on different soils, can safely be tilled without special technique, what sorts require various special methods, what slopes should be kept in grass or trees, and what slopes are too steep for even pastures but should be forested.

The rapid destruction of the land by erosion in Indiana, except on very gentle slopes, adds clear evidence of the need of extensive withdrawal of such land from cultivation. Already a large share of the sloping lands of southern Indiana have, indeed, been almost irreparably damaged by erosion. Since hillsides in Indiana are well adapted for forest growth, if they have enough soil, and since there will soon be an urgent national need for more lumber, extensive reforestation should be strongly encouraged on the sloping lands of Indiana. Indeed in southern Indiana, at least, only the almost level land should, ideally, be tilled.

In 1921 a law was passed by the legislature providing for the virtual exemption from taxation of land officially classified as forest land, and not pastured. This was a step in the right direction, but it was quite inadequate as far as checking soil wastage is concerned, because little land has been so classified, and a large proportion of that little is flat land not subject to erosion.

A law exempting from taxation all wooded land on hillsides, whether pastured or not, doubtless would lead to a substantially increased use of hillsides for grass and trees, and hence to a real reduction in erosion. It would also be desirable to tax at a reduced rate hillside grass land, even if not yet wooded. If hillsides that are tilled were taxed double the rate used for almost level fields, soil wastage would be rather effectively reduced! Such excess taxation is justified partly because rapid soil removal results in injury to other lands, roads, and streams. (It is comparable to the heavy taxes on dogs because some dogs kill sheep. Sheep killed by dogs are paid for out of the dog tax. Similarly, under the proposed hillside tax, the tax paid by the landowner who farmed hillsides would be partly used to relieve the tax burden of the man who used his hillsides in such a way as to conserve the soil).

Auto-Planetabling, An Economical and Expeditious Method of Geographic Mapping

By Alfred H. Meyer, Valparaiso University

With the advent of a new economic era has come the widespread realization that the material welfare of human society of any region, and of the nation as a whole, is dependent more and more on the proper conservation and utilization of our natural resources. The so-called regional planning programs of local communities, of state, and of nation, are based on the geographic principle that man exists in vital, intimate, mutual relationship with all the forms of his environment, and that if man individually and collectively is to enjoy the richest fruits of his labors, there must be the closest and most effective adjustment of his activities to environmental conditions; in other words, a harmonious integration of the forms of the human occupance and the forms of the natural environment.

To carry out this principle of coördination of the cultural and natural forms of landscape, detailed statistics and inventory surveys are essential. Since government statistics do not cover all classes of geographic data and are not in a form so as to lend themselves to environmental or regional correlations (except for large political units, such as counties and, more recently, township units, in some areas), much original field investigation and mapping is necessary. This program invites the patient and proficient geographer whose peculiar province it is graphically to portray the distribution of the several physical and cultural classifications of landscape data, and to point out the vital organic connections and processes which express the inter- and intra-regional relationships of areas.

Without such a comprehensive geographic investigation, based on quantitative measurements, only an imperfect picture may be had of the true economic and sociological conditions of a community or of a region.

Adaptation of the plane table to motor-mapping

But complete inventory mapping, as every geographer knows, is, at best, a tedious and expensive process. Much of it depends on time-consuming footwork. It is true, the airplane in recent years has phenomenally accelerated geographic mapping, particularly in regions of rugged terrain and dense vegetation; but airplane mapping still must depend on a considerable amount of ground work to furnish the detailed inventory for interpreting the aerial mosaics. Accordingly, a mapping project of the Kankakee Marsh of Northern Indiana and Illinois recently led the author to try a simple experiment with what we may call auto-planetabling, a form of motorized mapping, operated single-handed. The experiment proved to be a considerable time-saver.

Equipment and Method

In planning or devising the mechanical equipment to carry out the experimental mapping, the writer was guided by inexpensiveness of material and simplicity of design—an improvised set-up, we might say,

which could be converted into a more permanent and efficient fixture, if desired, with little extra time and expense. The entire surveying outfit consisted of: (1) an ordinary plane table—a drawing board, with trough compass attached, resting by a ball and socket joint on the spindle of the tripod, together with a simple open-sight alidade (Fig. 1, *C*); (2) a frame of small, galvanized pipe attached to the steering column of the car to support the drawing board, instantaneously transferable from the spindle of the tripod onto the spindle of the fixture on the steering column, and vice versa, as needed (Fig. 1, *A*); (3) a distance meter gauge —revolution counter—secured to the right fender of the car, and connected by a linked series of heavy rubber bands with a bolt placed eccentrically on a revolving metal disk fixed to the hub-cap of the rear wheel

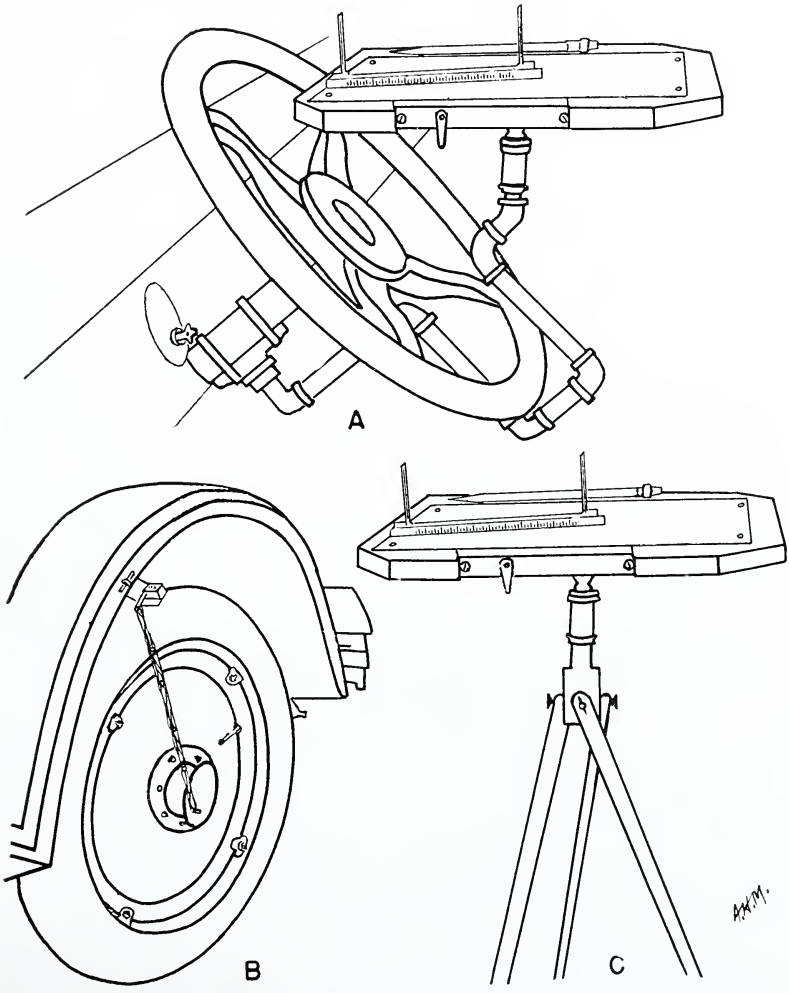


Fig. 1. Equipment for auto- and foot-planetabling.

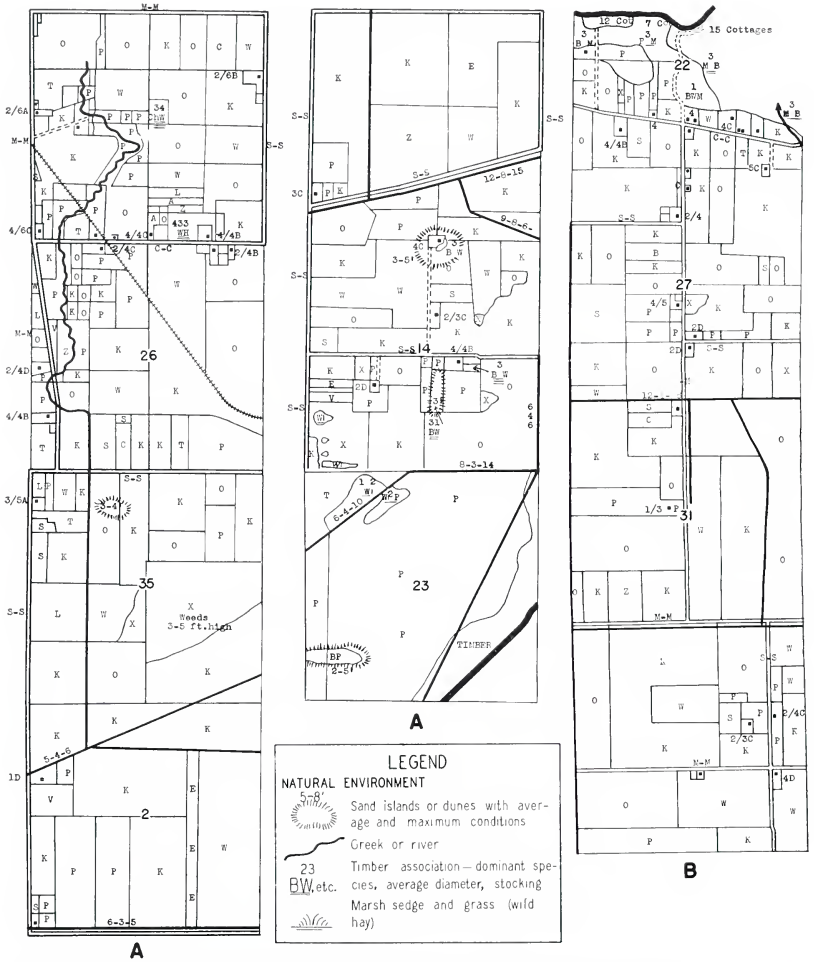


Fig. 2. Representative strip inventories mapped by the combined auto- and foot-planetabling method, showing in A, seven square-mile sections mapped in two days; in B, three and one-half sections completed in six hours.

(Fig. 1, *B*).[1] From this gauge, which registered the number of revolutions of the wheel from one stop to another, the field intervals, however small, could be plotted (8.9 revolutions, in this case, equalling one chain).

The procedure of auto-planetabling is essentially the same as ordinary foot-planetabling.[2] A sheet of mapping paper is affixed to the drawing board. The plane table is then set up, let us say, on a road intersection, sufficiently distant from the car to prevent the compass from being influenced by the car's magnetism. The board is then turned

[1]A speedometer adjustment graduated to give chain readings would, of course, be more convenient.

[2]Consult any surveyor's manual.

so that the compass points north, and a line is drawn along the alidade set in the line of sight of the road or route of travel. The board is now ready to be transferred to the support on the steering column, where it functions in the same way as on a tripod, except that preparatory to sighting a point or a line, instead of depending on the magnetically deflected compass for position, the board is turned into azimuth by placing the alidade on the road line previously drawn on the paper and sighting along the traveled road ahead or behind which serves as a guide in

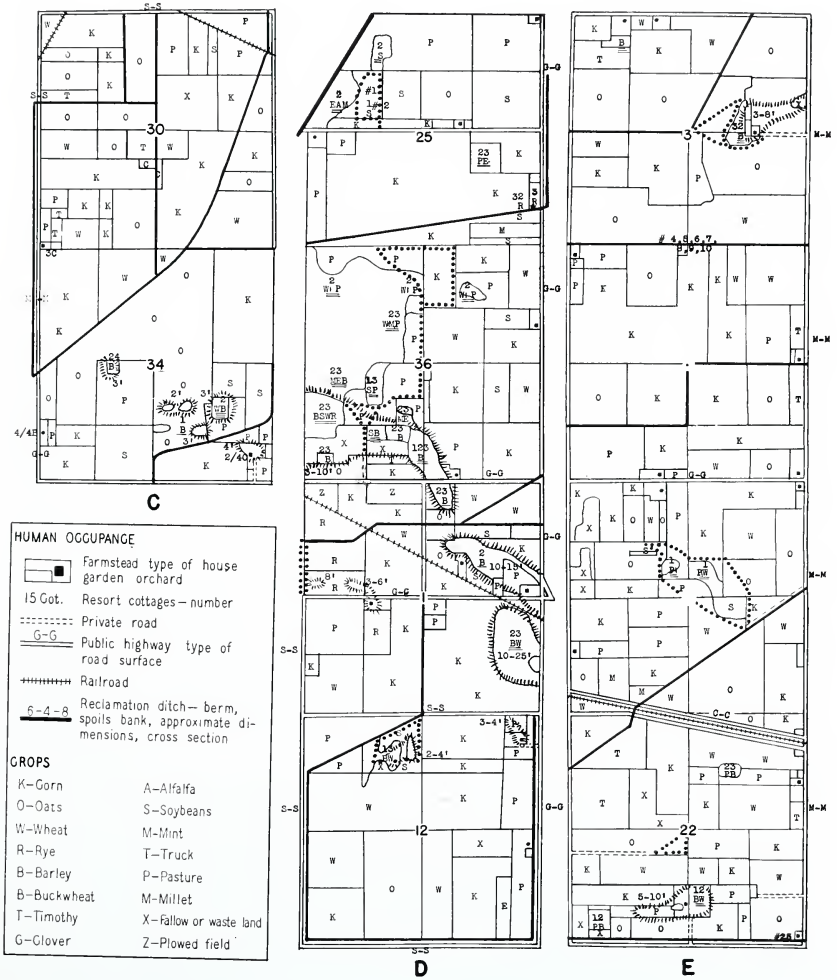


Fig. 3. Strip surveys illustrating the relation of auto- to foot-mapping as regards time and distance traveled. The west half of strip C was mapped in one hour with practically no footwork. Note in D and E the relative distances covered by car (along roads) and by foot (dotted lines); the ratio in D is about 2.5:1; in E, 5:1.

orienting the board.[3] It will be noted that the operation of the car and manipulation of the plane table is a one-man affair.

Having decided to stop at a certain point along the road to take one or several shots, as at a field boundary, we plot our position to scale as determined from the distance gauge, turn our board as outlined above, and then train the alidade on the line or point of the landscape to be charted, using our point of location on the board as a pivot. In addition to drawing in a field boundary directly, indefinite lines are drawn to fence corners or other landscape features readily visible and strategically placed to afford convenient intersections at the next stop and thus to determine the depth of fields or distances of objects without pacing.

In actual practice, where field units conform to regular forty-acre tracts or multiples thereof, few such intersectional lines need to be drawn, the mapper's eye becoming accustomed in time to judge field distances and proportionate dimensions quite accurately, as every geographer well knows. Because of the rapid succession of station stops, auto-planetabling seems particularly conducive to cultivating distance judging. Thus, in a flattish open country with rectangular fields, a strip, as much as a half-mile wide on either side of the road, or even wider, may be mapped without any intersecting lines.

Since much of the efficiency of car mapping depends on the extent of visibility of landscape features, it is highly essential to get the most suitable car for the purpose, one which permits a view in nearly every direction; the phaeton type represents the ideal, but the author got along with his landau sedan quite well. The author also found field glasses very useful, and frequently mounted the hood of his car, thus further extending the range of vision.

But even in a region most favorable to this type of car mapping, over any sizeable area one must expect to encounter conditions or features of one type or another which are so irregular or indistinct, if not altogether invisible, that in order to have contiguous a real inventory it becomes necessary to leave the car and complete the unfinished portion or section on foot. A very crooked boundary may have to be traced; timber may have to be inspected to determine association and stocking; crops hidden behind a ridge may need to be identified, etc. To complete this mapping, the drawing board is lifted off its base and set on the tripod for pedestrial mapping.

Sectional examples of auto-foot mapping

The extent to which the auxiliary auto-planetabling speeds up inventory mapping may best be seen by referring to specific sectional surveys, illustrated in the section-wide strip diagrams in Figures 2 and 3. These show the field, farmstead, and vegetation boundaries of the units mapped, together with other natural and cultural data as appear in the legend. On some of the strip surveys only a time record was kept for the combined auto-foot mapping. In connection with several others—strips *D* and *E* of Figure 3—the route actually traveled on foot to get

[3]The deflection-free compass doubtless would prove to be a convenient auto survey accessory.

at otherwise obscured lines or inaccessible data was plotted, thus revealing the proportionate distances of foot travel to car travel.

Except for the narrow swamp and river-ditch features, details of which were taken from an engineer's map, the seven sections shown in Figure 2, *A* were mapped in two days, despite the temperature's rising as high as 100° and 104° F., respectively.

Strip *B* (Fig. 2), comprising over three and one-half sections, was mapped from one o'clock till dusk, a farmer being consulted for a few crop data. The rectangularity of fields and conveniently aligned roads made pacing almost entirely unnecessary, except along the river swamp where several clusters of resort cottages, connected with the main highway by a winding road, necessitated abandoning the car.

A short time record for exclusive car planetabling is illustrated by strip *C* of Figure 3. The west half of the two sections was completed in about one hour, without getting out of the car.

A more exact impression of the relation of auto- to foot-mapping may be had by consulting strips *D* and *E* of Figure 3, where the actual routes and distances covered by auto and on foot respectively may be compared and associated with conditions in the field. In *D* the total distance traveled on foot, including return to the car, amounted to four and one-half miles, as compared to eleven miles traveled by car. The western half of Section 36, it will be noted, called for considerable footwork on account of the irregular forest and pasture lines unbounded by roads.

The area shown in strip *E* was particularly well adapted to auto-planetabling, requiring only two and three-fourths miles on foot, as compared to fourteen miles by car. One section, No. 10, was exclusively car-mapped.

Types of landscape and inventory

The rate of progress inany geographic survey depends much on the conditions of the landscape and the number of details charted or otherwise recorded. A brief description, therefore, of the features of the Kankakee landscape is essential in properly evaluating this type of survey.

Except for sectional sandy, dune-like knobs and ridges, the Kankakee exhibits a markedly flat terrain with an average gradient of about one-third foot per mile from the head of the valley at South Bend, Indiana, to the western extremity of the original marsh at Momence, Illinois; its cross section has a correspondingly low gradient. The dunal islands which are scattered quite regularly through the valley are conspicuous for their elevation above the flattish terrain, a phenomenon accentuated by the farmsteads which characteristically surmount them. These elevated tracts range from a mere mound, barely large enough to accommodate a single farmstead, up to a section or so; they vary in height from a few feet to as much as 30 or 35 feet (commonly 5-10 feet), and are variously shaped, from circular knobs to very sinous ridges (Fig. 4).

At times interfering with the otherwise excellent visibility offered by the flattish terrain, these dune eminences now and then served as useful vantage points to shoot at or from; but their outlines frequently called

for extra footwork in order to record the irregular field patterns which they typically produce.

Natural cover conditions in the Kankakee did not constitute a major handicap in mapping. Only in the Swamp rimming the Kankakee River do we find an extended timber stand irregularly bounding fields and pastures. Tree clusters of oak characteristically surmount and accentuate the dunal eminences on the reclaimed marsh prairies.

Geographic inventory included practically every natural and cultural form, excepting soils, which had previously been mapped by federal and state surveys. The various categories of field data charted are shown in the legends of the representative field sheets referred to above (Figs 2 and 3). In addition, notations were made from personal observations and interviews with farmers, together with a detailed record of photographed landscape phenomena. All these are included within the time schedules set forth above.

Summary and Conclusions

Auto-planetabling is a simple and economical form of motorized mapping intended to expedite detailed inventory studies of landscapes. It recommends itself not as a self-sufficient type of survey, but as a convenient and efficient aid to other methods of surveying in speeding up ground coverage.

This method was applied experimentally to the extensive and intensive mapping of the Kankakee region of Northern Indiana and Illinois, in which connection it has demonstrated its time and energy-saving value as compared to the exclusive pedestrial survey. Time records kept on several strip surveys indicate a total of almost twelve square-mile sections completed by the combined auto-foot mapping in three days; a number of sectional surveys show, on an average, that three-fourths of the total distance traveled was by car.

Auto-mapping saves time not only in traveling but also in actual mapping, since the plane table is ready for use the moment the car stops.

While this type of survey is of particular advantage in a prairie country with a well-developed rectangular road pattern, as is exemplified by the Kankakee reclaimed marsh, its advantageous use is not confined to such an area. Even in a region of considerable ruggedness, auto-planetabling may prove advantageous in strip mapping along roads or in reconnaissance surveys, and thus furnish a rapid basis for sampling landscape characteristics so essential in interpreting aerial mosaics.

Oölites in the Green River Formation of Central Utah, and the Problem of Oölite Growth

Stuart L. Schoff, DePauw University

Oölitic limestone occurs in the Green River formation, of Eocene age, at Manti, in central Utah. A microscopic study of thin sections of the rock suggests conditions under which the oölite originated.

As described by Bradley (1), and others, the Green River formation was deposited in a great fresh-water lake, or several lakes—an environment contrasting strongly with the highly saline environment of Great Salt Lake, where oölitic grains are now forming, and less strongly with the marine conditions under which many oölites of the geologic column probably originated.

Description.—The oölites are composed of calcium carbonate, chiefly as calcite, with an admixture of silt. Some of the material has been recrystallized, and some is now silicified. The average diameter of the grains is between 0.4 and 0.5 mm. They are circular in cross-section, elongate or oval, triangular, and irregular. In general, the outline conforms with the shape of the nucleus, if one is present, but there are grains in which the outer zones are eccentric (Fig. 1, *A*).

Uncommonly the oölitic grains contain mineral fragments as nuclei, but, even under high magnification, the centers of most of the grains appear simply as structureless spherical bodies of the same material as the rest of the grain. Hence the nuclei suggest little as regards causes for precipitation of calcium carbonate.

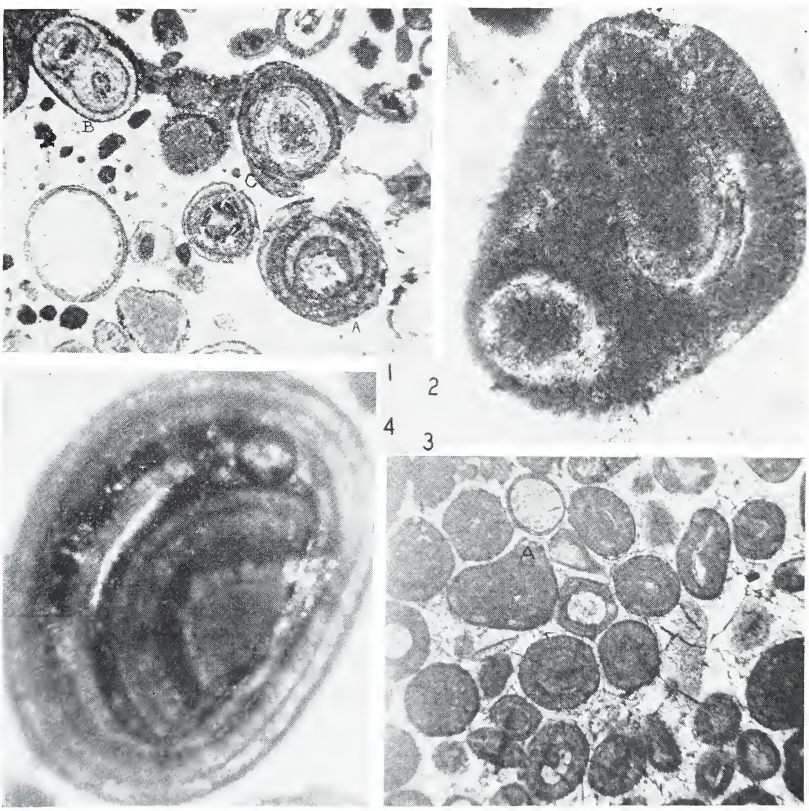
Figure 1, *B* and Figure 2 illustrate grains with two centers of growth. One grain with three centers was noted. Concentric zones are present in some of the centers as well as in the outer zones, without the irregularities that might be expected if one growing grain absorbed a neighbor. Growth must have started at two adjacent loci at nearly the same time and continued without mutual interference until deposition was taking place about the two together. It hardly seems that the grains could have grown together if they were being rolled about by waves.

The grains at *A* in Figure 3 are closely spaced and irregular in shape. The irregularity is thought to be due to mutual interference during the later stages of growth, because in some grains, at least, the distortion is confined to the outer zones. Schrock (2) offered this explanation for the polyhedral shape of pisolites in a glacial cobble collected near Logansport, Indiana. This phenomenon is further evidence that the grains were not agitated while growing.

The concentric zones in some grains are of different thickness on different sides, yet there seems to have been no abrasion. It appears possible that the side with the thin part of the zone was resting on the bottom, and therefore grew more slowly. Thus Davidson and McKinstry (3) placed a small piece of andesite in a nearly stagnant pool of water in a cave and, after a year and a half found a coating of crystalline calcium carbonate between 1 and 2 mm. thick on the andesite. The deposit was thinner on the bottom than elsewhere. The andesite had not been

rolled over, and the authors suggest that oölitic grains might form similarly without rolling.

Figure 4 illustrates an oölitic grain which contains a fragment of another grain as its nucleus. Concentric structure is well developed in both the nuclear fragment and the material built around it, the later zones conforming to the shape of the fragment. The similarity between the broken grain and other oölitic grains of the same rock suggests that it belongs to the same generation rather than an earlier one. This fragmentation indicates wave or current action, and supports the idea that oölitic grains grow while rolling about. However, in the same rock there are other grains possessing two growth centers—suggesting growth in an undisturbed medium. Probably, then, periods of quiet alternated with periods of agitation. Grains developed at rest were broken up by being washed about, and the fragments became nuclei for later oölitic grains of the same general series—formed, perhaps, during a succeeding period



Figs. 1-4. Fig. 1. *A*, outer zones concentric; *B*, grain with two growth centers; *C*, grain with an incomplete outer zone, probably indicating secondary growth. x 15. Fig. 2. Oölitic grain with two centers of growth. x 40. Fig. 3. *A*, grains with irregular shapes because of mutual interference during growth. x 15. Fig. 4. Grain a fragment of an earlier grain as a nucleus. x 40.

of quiet. If ordinary storms were responsible for the disturbance, growth may have been rather rapid, and the supply of calcium carbonate correspondingly abundant.

The internal structure of the oölitic grains is characteristically concentric, only a very few of them having even a suggestion of radial structure. Even in these few, concentric structure is dominant. Eardley (4) has shown that the carbonate part of the growing oölites from Great Salt Lake is mostly aragonite in concentric bands. Because aragonite is unstable, it alters to calcite with development of radiating structure, yielding a grain combining, in many cases, a concentric and radial structure. The absence of radial structure in the oölite from Manti suggests, therefore, that no alteration has taken place and implies precipitation of calcium carbonate as calcite rather than aragonite. Cause for this difference in mineral composition of newly formed oölitic grains of Great Salt Lake and those of the Green River formation may be found in the difference in environment—the Green River lakes being fresh water, and Great Salt Lake being extremely saline.

Figure 1, *C* shows incomplete outer zone that probably was added after normal growth had ceased. The additional material may have been derived from the surrounding matrix, or aqueous solutions bearing material from an outside source may have been able to reach the grain on only one side.

Origin of Oölites.—There is little organic matter in the oölite from Manti and therefore little to show that organisms such as algae or bacteria were effective. Twenhofel (5) has shown that oölitic grains can be formed artificially, without intervention by organisms, under conditions that would permit rolling. On the other hand, Bucher (6) suggests that oölitic grains grow in a colloidal emulsion and that rolling during growth is unlikely because agitation of the suspending or dispersing medium would not allow development of oölitic structure. He found that the amount of impurity determines whether the growing grain will have radiating or concentric structure, but Spencer (7) says that concentric zoning depends on checking or slowing the rate of crystallization.

Oölitic fragments in the oölite from Manti indicate wave or current action, but grains with two growth centers, distortion of shape due to mutual interference during growth, and variations in thickness of outer zones all indicate a quiet medium. It appears, then, that the oölite may have formed in a colloidal emulsion during periods of quiet, interrupted by periods of agitation.

Acknowledgments.—E. M. Spieker, of The Ohio State University, directed the work and supplied the rock specimens. E. Willard Berry and the late W. A. P. Graham, then of the University, C. F. Moses, of Muskingum College, and W. H. Bradley, of the U. S. Geological Survey, advised the writer on various phases of the problem. E. R. Smith, of DePauw University, read and criticised the paper.

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PROGRAM OF THE SECTION ON MATHEMATICS

Chairman: R. B. STONE, Purdue University

1. The multi-dimensional operational calculus. Albert E. Heins, Purdue University.
2. On a class of ruled surfaces generated by an algebraic correspondence. C. G. Schilling, Purdue University.
3. The significance of the Literary Digest Poll for 1936. Will E. Edington, DePauw University.
4. A group of projective transformations associated with a conic section. Alson H. Bailey, Central Normal College.

On a Class of Ruled Surfaces Generated by an Algebraic Correspondence

C. G. SCHILLING, Purdue University

Introduction. The (n,n)—Correspondence with complete symmetry between λ and μ was first set up by Emch[1] as follows:

$$(1)\quad \prod_{i=1}^{n+1}(\lambda-\lambda_i)\prod_{i=n+2}^{2n+2}(\mu-\lambda_i) - \prod_{i=1}^{n+1}(\mu-\lambda_i)\prod_{i=n+2}^{2n+2}(\lambda-\lambda_i)=0.$$

In this relation the parameters λ and μ determine two geometric entities of the same kind uniquely. Furthermore, these parameters are related by (1) in such wise that an arbitrary choice for $\lambda(\mu)$ together with the n values thereby determined for $\mu(\lambda)$ form an involutorial set of $n+1$ numbers. Relation (1) represents a curve of order $2n$ and genus $(n-1)^2$.

In this investigation Zeuthen's formula[2]

$$(2)\quad y_1-y_2=2x_2(p_1-1)-2x_1(p_2-1)$$

is of importance. This formula applies when there exists between two carriers C_1 and C_2 of genera p_1, p_2 respectively, an $(x_1, x_2)-$ correspondence of such a nature that among the $x_1(x_2)$ points on $C_1(C_2)$ that correspond to one point on $C_2(C_1)$ it happens $y_1(y_2)$ times that two points coincide.

1. The Ruled Surfaces F_{4n}.

Let the parameter $\lambda(\mu)$ determine the planes of a pencil on generic line t and the parameter $\mu(\lambda)$ the osculating planes of a space cubic. If λ and μ are related as in (1), a surface F_{4n}, ruled and non-developable, of order $4n$ and genus $(n-1)^2$, is generated. From each point of the line t three planes osculating the cubic can be drawn, and, due to the continuity of (1), all these planes will be determined. To each plane corresponds n lines which lie in it. Line t is therefore a $3n$-fold line on the surface. Hence the $3n$ lines through any point of line t lie in three planes, n lines in a plane.

Between the points of line t and of the space cubic there is a (1,3)-correspondence. Then by Zeuthen's formula, (2) above, there are four coincidences. These are due to the four points where the line t intersects the developable on the cubic. The line t intersects four lines on this developable, and these lines are formed by the intersection of two consecutive osculating planes of the cubic. Hence, there are n torsals at each of these four points, a torsal point being one in which two consecutive generatrices of the surface intersect.

The work of Wiman[3] is useful in any investigation of the fundamental characteristics—multiple curve, torsals—of a ruled surface. The formulas we apply in the following are due to Wiman. The number of torsal points on the $3n$-fold directrix is

$$2(r+p-1)=2n^2+2n$$

[1]Emch, 1932. Amer. Jour. **54(2)**:285.
[2]Zeuthen, 1871. Math. Ann. **3**:150.
[3]Wiman, Acta Math., 1895-7. **19-20**:63.

where p is the genus of the surface and r the multiplicity of the directrix. The number of torsal points on the surface outside of those on the directrix line is

$$2(n-r+p-1)=2n^2-2n$$

making a total of $4n^2$ torsal points on the surface.

We wish to investigate what effect the roots of $\triangle=O$, where $\triangle$ is the discriminant of (1), have on the surface F_{4n}. The equation $\triangle=O$ is of degree $2n(n-1)$ in $\lambda(\mu)$, and its roots separate into $2n$ sets of $(n-1)$ numbers each, each set giving the same double root. The two sets of values, the λ-set and the μ-set, given by (1) are indistinguishable. Hence the roots of $\triangle=O$ represent both sets. First, consider these roots as μ-values, and let line t carry the μ-planes and the cubic the λ-planes. Then each of one of the above named sets of $(n-1)$ μ-planes on t determines, among others, the same two consecutive λ-planes on the cubic. Thus are formed torsal points which lie on a line of the developable on the cubic. Clearly there are $2n^2-2n$ such torsal points since there are $2n$ such sets of $(n\text{-}1)$ roots of $\triangle=O$. If the roots of $\triangle=O$ are considered as λ-values then $2n^2-2n$ torsal points are formed on the $3n$-fold directrix line t.

These same results might have been obtained by using Zeuthen's formula (2) on the $(1,n)$-correspondence that exists between the points on either carrier and the lines on F_{4n}. We observe that $4n$ of the torsal points on the surface are not accounted for by the roots of $\triangle=O$. These are independent of the relation (1) and are determined by the choice of line t. They always occur in sets of n at the four points where line t strikes the developable on the cubic. They are part of the multiple curve, the $3n$-fold directrix, but the residual double curve does not pass through them.

The torsal points of the surface not on directrix line t lie on $2n$ lines, $(n\text{-}1)$ on a line. The torsal points of the surface on line t are so arranged that the torsal lines on t lie in sets of $(n\text{-}1)$ each in $2n$ planes on t.

Through the line t pass $3n$ sheets of the surface in such a manner that the $3n$ lines through any point of t lie n at a time in three planes. Exceptions occur only for the roots of $\triangle=O$, causing two of the planes to coincide thereby producing torsals as already found. Hence the surface has no double lines or stationary lines.

A generic section of the surface is a curve of order $4n$ and genus $(n\text{-}1)^2$. It has $7n^2-4n$ nodes, $\frac{1}{2}3n(3n\text{-}1)$ of which are due to the $3n$-fold directrix line on the surface. Hence, there is a residual double curve on the surface of order $\frac{1}{2}5n(n\text{-}1)$. By a formula due to Wiman the genus of the residual double curve is

$$\begin{aligned} p' &= \tfrac{1}{2}(n'\text{-}r\text{-}2)\ (n'\text{-}r\text{-}3) + p(n'\text{-}r\text{-}2) - D^* \\ &= \tfrac{1}{2}(n\text{-}2)\ (2n^2\text{-}3n\text{-}1) - D. \end{aligned}$$

The number D (actual double points on the double curve) is increased by 2 for each double line on the surface and by 1 each time that two torsal lines cross. Since neither possibility occurs for the surfaces F_{4n}, $D=O$ and the genus of the residual double curve is

$$p' = \tfrac{1}{2}(2n^3-7n^2+5n+2).$$

II. The Rational Case.

In this case line t is a triple line and on it are four torsal points where this line intersects the developable of order 4 on the twisted cubic. There is no residual double curve.

*In this formula n' denotes the order of the ruled surface.

We now proceed to map a plane into a rational, ruled quartic surface in S_5 and then to project this surface into S_3 thereby obtaining the above determined ruled quartic. This method of examining a surface, by first obtaining it as a normal surface, is useful in viewing the special properties of a surface, such as the double curve, torsals and multiple points, if any.

In the plane π take a system of rational quartics with a fixed triple point and three fixed single points. There are ∞^5 such quartics, and any two members of the system intersect in four free intersections. Now map the plane π by means of this system into an S_5 as follows:

$$(3) \quad \sigma y_i = \phi_i(x), \qquad i = 1,2,3,4,5,6$$

where the $\phi_i(x)$ are the six linearly independent quartics on the four base points. Then in S_5 is obtained a rational, ruled, normal quartic surface F. There are two types of surface F in S_5, (a) one with an ∞^1 system of directrix conics and the other (b) with a directrix line. Mapping by (3) gives type (a). A base point of order k in plane π maps into a rational curve of order k in S_5. Then the base points of the system (3) map into corresponding rational curves To the sections of F by hyperplanes correspond projectively the curves of the system (3). Then all sections of F by hyperplanes are rational and the surface F must necessarily be ruled.

The surface F has ∞^1 directrix conics; any such conic is determined by one point of F and no two conics intersect.[5] To understand this statement consider the ∞^1 system of conics in π on the four base points. A conic in π maps into a curve of order 8 but from this octic splits off three lines and a cubic leaving a conic on F. There are ∞^1 of these on F, as in π, and each is determined by one point on F, just as in π one point in the plane determines a conic of this pencil, and this one point maps into just one point on F. No two conics on F intersect since no two conics of the pencil intersect in any points outside of the base points.

This surface F also contains ∞^3 directrix cubics any such curve being determined by three points of F. All these can be obtained as hyperplane sections of F residual to any given generator. This statement is clear when we consider in plane π the rational cubics through the four base points and with a double point at the triple base point. By the mapping a cubic goes into a C_{12} but from this twelve-ic splits off two cubics and three lines thus leaving a cubic. Since any three points in π outside of the base points determine one of these cubics in π, then any such directrix cubic is determined by three points on F. In the plane π any two of these cubics intersect in two free points, hence on F any two of the directrix cubics do likewise. There are ∞^3 such cubics in π, hence that many on F. This normal surface in S_5 can now be projected from a line in S_5, and the ruled quartic we have studied in S_3 is obtained.

III. The Dual Surfaces. Γ_{4n}.

Let the parameters λ and μ in (1) determine points on the generic line t and the twisted cubic C_3 in S_3. Then a ruled surface of order $4n$ and genus $(n\text{-}1)^2$ is generated by joining corresponding points. Line t and the twisted cubic are n-fold directrices on the surface. A generic cross section of this surface is a curve of order $4n$ and genus $(n\text{-}1)^2$. It, therefore, has $7n^2-4n$ nodes, of which $2n^2-2n$ are due to the four n-fold points caused by the two directrices. Hence, the surface has a residual double curve, call it the b-curve, of order $5n^2-2n$.

[5]Edge, 1931. Ruled surfaces. Cambridge University Press.

Each generator of the surface is cut by $(4n\text{-}2)$ others of which $(n\text{-}1)$ are at each of its points on a directrix, thus discarding $2n\text{-}2$ in all. Then the residual b-curve of order $5n^2-2n$ is generated by the $(4n\text{-}2)-(2n\text{-}2)=2n$ points, in which each generatrix is cut outside the directrices. As before, the roots of $\triangle=O$ may be considered as λ- or μ-values and in each case $(2n^2\text{-}2n)$ torsal points are determined on one of the directrices. The surface has $4n$ additional torsals, as given by the general formula. These arise, n at a time, at the four points where the line t intersects the developable of order 4 on the cubic. They are on the twisted cubic and the residual b-curve does not pass through them.

As in the case of its dual F_{4n}, this surface has no double lines, and therefore no stationary lines. A section of Γ_{4n} by any plane through t is a curve of order Γ_{4n} consisting of an n-fold line and three sets of n concurrent lines. Hence, there is a $(1,3n)$-correspondence set up between the planes on t and the lines on $4n$. By Zeuthen's formula (2) there are $(2n^2+2n)$ coincidences of lines. These coincidences are torsal points on the directrix C_3, and we have already observed that along this cubic there are $2n^2-2n+4n=2n^2+2n$ torsal points. Any plane on t cuts the residual b-curve in $(5n^2-2n)$ points. In this plane are 3 sets of concurrent lines, n lines in a set. Outside of the intersections at the vertices of the pencils, these lines intersect in $\frac{1}{2}3n(3n\text{-}1)-3\cdot\frac{1}{2}n(n\text{-}1)=3n^2$. That is to say, any plane on line t cuts the b-curve in $3n^2$ points outside of line t hence $2n^2\text{-}2n$ points of the curve are on line t. These are the torsal points on t as already found.

The genus of the residual b-curve of order $(5n^2\text{-}2n)$ can be determined by the correspondence between the points of the b-curve and the lines of the surface. Each point of the curve corresponds to the two generatrices through it, and each generatrix passes through $(4n\text{-}2)-(2n\text{-}2)=2n$ points of the b-curve, hence, a $(2n,2)$-correspodnence between points on the curve and lines on the surface. No torsal points of the surface occur off the two n-fold directrices, hence no coincidences in this correspondence. Now apply Zeuthen's formula (2):

b-curve: $x_1=2n,\ y_1=O,\ p_1=?$

Surface: $x_2=2,\ y_2=O,\ p_2=(n\text{-}1)^2$.

Then $p_1=n^3-2n^2+1=(n\text{-}1)\ (n^2-n-1)$, and this is the genus of the residual double curve. As before, the rational surface of this class can be obtained by first mapping the plane into a quartic in S_5 with a directrix line.

A Group of Projective Transformations Associated with a Conic Section

Alson H. Bailey, Central Normal College

The conic is variously defined in college textbooks on projective geometry as the projection of a circle on a plane, as the locus of the points of intersection of corresponding lines of two projective, non-perspective pencils in the same plane, or as the locus of the point from which four given fixed points are projected by lines making a constant cross ratio. Still another characteristic property of the conic has been used to define it, but this has been made use of rarely: first von Staudt in his *Geometrie der Lage* (1847) considered the locus of the self-conjugate points of a general plane polarity having at least one such point and proved that the locus is a conic section; in recent years Enriques used this property as his definition in his textbook on projective geometry but did not follow it consistently in his discussions. At the suggestion of Professor Tibor Radò of The Ohio State University, I undertook the problem of developing some of the projective properties of the conic from the definition in terms of a polarity and attempted to carry out systematically the plan introduced by Enriques. The present paper gives a brief summary of some of the steps in this discussion of the conic. The plan may be of interest to an advanced undergraduate class in projective geometry, perhaps as material for special or honors work in addition to the usual first course in the subject, because of the use made of some rather simple concepts not generally given consideration in elementary courses, particularly the unusual definition of the conic and the properties of projectivities in the plane and of groups of projective transformations.

The familiar properties of the conic as a curve of the second order and class follow readily from the study of self-conjugate elements in a polarity so that such considerations will be omitted from this summary. Also the general theory of poles and polars with respect to a conic is an immediate consequence of the definition of the conic itself.

As a means of securing unity in the discussion of other topics it was found convenient to associate with the conic a particular group of projective transformations. If we suppose the conic k is given as the self-conjugate points of a polarity P in the plane π, then the class of all collineations in π which transform k into itself is a group, which may be denoted as $G(P)$. Formally, the collineation C belongs to $G(P)$ if and only if

$$C^{-1} \; P \; C = P.$$

Each element of $G(P)$ either is an involution (a collineation of period two) or is a collineation which may be represented as the product of two involutions. The involutions of $G(P)$ are therefore of special interest.

Every point-and-line which are paired by the polarity in π and which are not coincident belong to a unique involution of $G(P)$, the point and line being center and axis of the involution, respectively.

Either center or axis is sufficient to determine the involution. This correspondence between points or lines of the plane and the involutions of $G(P)$ makes possible a computational method for deriving relations among the points and lines of a figure. The following theorem was found especially useful in considerations of conjugacy of points or lines:—The product of two involutions in $G(P)$ is commutative if, and only if, the centers are conjugate in P, that is, if each center lies on the axis of the other involution.

Furthermore, if two involutions are commutative, their product is a third involution, and the three involutions so related together with the identity form the four-group. The three centers are the vertices of a self-polar triangle.

The non-identical collineations of $G(P)$ belong to three classes according to the type of figure formed by their fixed elements: (a) a triangle with two vertices on the conic and a third not on the conic, the sides and vertices comprising the totality of fixed lines and points, respectively; (b) a tangent and its pole, the point of contact with the conic; (c) a line not intersecting the conic and its pole.

A general collineation of G (P) has associated with it a fixed line on which are found the centers of its factor involutions and each point of which that is not a point of intersection with the conic is the center of one such factor. From the previous remark concerning commutative involutions it is seen that the factors of an involution have centers lying on the axis of the involution. This line on which the centers lie is the axis of the collineation.

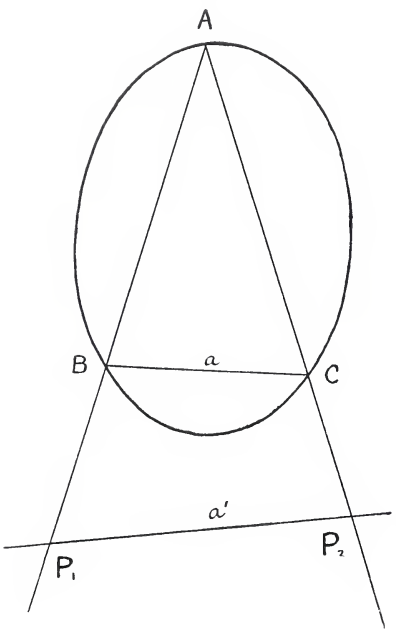
A collineation of $G(P)$ is determined uniquely when the points which correspond to an arbitrary set of three points on the conic are prescribed. There is, therefore, an isomorphism between the group $G(P)$ and the group of projectivities of points on the conic. This suggests a connection between the present treatment and the usual theory of projectivity on a conic.

A collineation is uniquely determined when an arbitrary line of the plane is prescribed as axis and the image of a single point of the conic is given, the image necessarily being chosen on the conic also, as the collineation must transform the conic into itself. Two collineations may have the same fixed elements and yet be distinct. All collineations sharing the same figure of fixed elements form a subgroup of $G(P)$.

These properties just outlined and others not listed make possible rather simple proofs of some of the standard theorems on the conic. The theorem of Pascal on the inscribed hexagon may be demonstrated by defining a collineation in $G(P)$ which carries three alternate vertices of the hexagon into the other three in a properly chosen order, and then noting that the pairs of opposite sides of the hexagon meet in points which are centers of factor involutions of the collineation and which must lie on the same line, the axis. This type of proof may be applied to the special cases of inscribed pentagon, quadrangle, and triangle without reference to the usual continuity argument.

The proof of a theorem due to von Staudt illustrates the method of proof by computations with involutions in $G(P)$.

THEOREM: If a line intersects two sides of a triangle inscribed in a conic in a pair of conjugate points, the line is conjugate to the third side, and conversely.



Let the inscribed triangle be ABC and suppose the line a' intersects AB and AC in the conjugate points P_1, P_2 respectively. Let I be the involution with axis a' and let I_1 and I_2 be those with centers P_1 and P_2 respectively. (Questions concerning the existence of these involutions, such as occur when a' is a tangent or P_1 lies on the conic, need not be considered, for in that case the proof is immediate without the use of the involutions.)

If P_1 and P_2 are conjugate, the product I_1I_2 is commutative and is an involution in $G(P)$,—in fact, the involution I since the centers lie on its axis a'. Now I carries B into C, for, in the product I_1I_2, B is taken into A by I_1 and A into C by I_2. This implies that the center of I lies on BC and hence a' is conjugate to the side $a=BC$.

The converse may be demonstrated in similar fashion.

In conclusion, attention is called to the fact that the above theorem is useful in proving the theorem of Steiner, which asserts that the points of a conic are projected from any two of its points by projective pencils of lines. This now brings the discussion into the channels followed by most texts in projective geometry.

PROGRAM OF THE SECTION ON PHYSICS AND ASTRONOMY

Chairman: GEORGE W. HORTON, Wabash College

1. Theoretical studies: (1) Heaviside layers and electronic waves; (2) Preliminary report on the mathematics of the motions of a glacier. Oliver E. Glenn, Lansdowne, Pa.
2. The addition of two frequencies in audio-apparatus. D. B. Green, Ohio University.
3. A convenient source of light giving the mercury lines. R. R. Ramsey, Indiana University.
4. Peculiar deposits in tungsten lamp globes. J. B. Dutcher, Indiana University.
5. An audio-frequency generator for laboratory use. R. R. Ramsey, Indiana University.
6. Discharge of electricity from the leaves of forest trees. Gaylord S. Kurtz, Fort Wayne.
7. Polarization phenomena in scattered light. J. B. Dutcher, Indiana University.
8. The square foot as a unit of sound adsorption. C. T. McCormick, Indiana University.
9. Study of super-sonic sound speeds in gases. J. E. Crites, Jr., Indiana University.
10. Wave velocity and intensity. Arthur L. Foley, Indiana University.
11. Ratio of acoustical to electrical and mechanical units. R. B. Abbott and C. Fry, Purdue University.
12. Laws of conservation and theory of measurement. E. S. Akeley, Purdue University.
13. The Purdue Cyclatron. J. D. Howe, Purdue University.
14. Coördination in liquids and the structure of molten salts. K. Lark-Horovitz and E. P. Miller, Purdue University.
15. Fourier analysis with mechanical methods. E. P. Miller, Purdue University.
16. Wave mechanical determination of the electrical resistance of the monovalent metals. E. L. Peterson and L. W. Nordheim, Purdue University.
17. Second order spin effects in the H-3 nucleus. R. D. Present, Purdue University.
18. Radiative capture of protons by carbon. F. L. Yost, Purdue University.
19. On the emission of gamma radiation during the beta decay of nuclei. J. K. Knipp, Purdue University.
20. Faraday effect in the x-ray region. H. T. Clark, Purdue University.
21. X-ray investigation of mixtures of polymorphous substances. S. E. Madigan and K. Lark-Horovitz, Purdue University.
22. Paper, title to be furnished. H. M. James, Purdue University.

The following title was not included in the published program, but the paper is published in this volume.
A cold-cathode rectifier. Charles T. Knipp, University of Illinois.

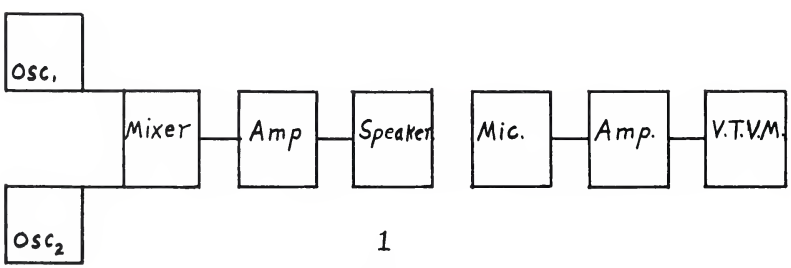
Dr. Leslie I. Steinbach, of Central Normal College, was elected chairman of the section for 1937.

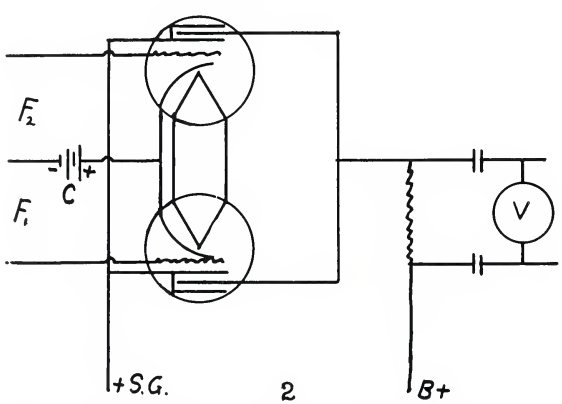
The Addition of Two Frequencies in Audio Apparatus

D. B. Green, Ohio University

Frequency characteristics of loud speakers are always measured with a single frequency, varied over the audio range. In musical reproduction this is almost never the actual situation as there is at least a soloist with accompaniment or even an entire orchestra or chorus. It occurred to Professor R. R. Ramsey of Indiana University to measure the frequency characteristic with two frequencies impressed simultaneously on a speaker. Preliminary work by Robert Duffy, using a carbon microphone as a pick-up device, indicated that there might be some interesting results; so the problem was taken up under the direction of Professor Ramsey.

The ribbon microphone was chosen as a pick-up device because of its better stability and convenience in not requiring a polarizing voltage. The apparatus in block diagram is shown in Figure 1. It consists of two oscillators kept at different frequencies feeding into an electronic mixer, amplifier, and speaker. The sound from the speaker is picked up by the ribbon microphone feeding a preamplifier, which actuates a vacuum tube voltmeter. In order to make measurements, a mixing device was required which would prevent the output from one oscillator feeding into the other oscillator. The electronic mixer shown in Figure 2 consists of two





Figs. 1, 2. Fig. 1. Block diagram of apparatus. Fig. 2. Electronic mixer.

screen grid tubes with grids driven by the two oscillators, respectively, and with the plates in parallel receiving the plate current through a common plate-coupling resistor.

The procedure was to adjust the output of one oscillator to a certain level, as measured through the system by the vacuum tube voltmeter, stop the first oscillator, adjust the second oscillator to a measured level in the same manner, then start both oscillators, and measure the resulting output.

Many measurements were made over the audio range at different levels all showing that the sum of two frequencies is the square root of the sum of the squares of the individual values. Figure 3 shows the result of adding a constant frequency of 800 cycles to a variable frequency from 100 to 6000 cycles. The straight line is the theoretical square root of the sum of the squares. The plotted points show the close agreement with the experimental result.

The theoretical result is obtained as follows:

Let $E_1 \sin \omega_1 t$ be the voltage of the first frequency, and $E_2 \sin \omega_2 t$ be the voltage of the second frequency. Then the effective value of the sum of the two waves is:

$$S = \sqrt{\int_0^{t_1} (E_1 \sin \omega_1 t + E_2 \sin \omega_2 t)^2 \, dt}$$

where the limit, t_1 is chosen to include an integral number of cycles of both waves.

$$S = \sqrt{\frac{E_1^2 + E_2^2}{2}} = \sqrt{\frac{E_1^2}{2}\text{ eff.} + E_2^2\text{ eff.}}$$

The author wishes to suggest the following equation as a general statement giving the sum of two waves of any frequency and any phase difference.

$$S = \sqrt{a^2 + b^2 + 2\,ab \cos \Theta}_{\text{av.}}$$

Where a is the effective value of the voltage of one frequency, b is the other and $\cos \Theta_{\text{av.}}$ is the average value of the cosine of the phase angle between the two frequencies.

Figure 4 shows two waves of the same frequency and in the same phase. Placing Θ equal to zero in the general equation, we have

$$S = a + b.$$

Figure 5 shows two waves of the same frequency but opposite phase. Placing $\Theta = 180$ degrees in the general equation we have the familiar

$$S = a - b$$

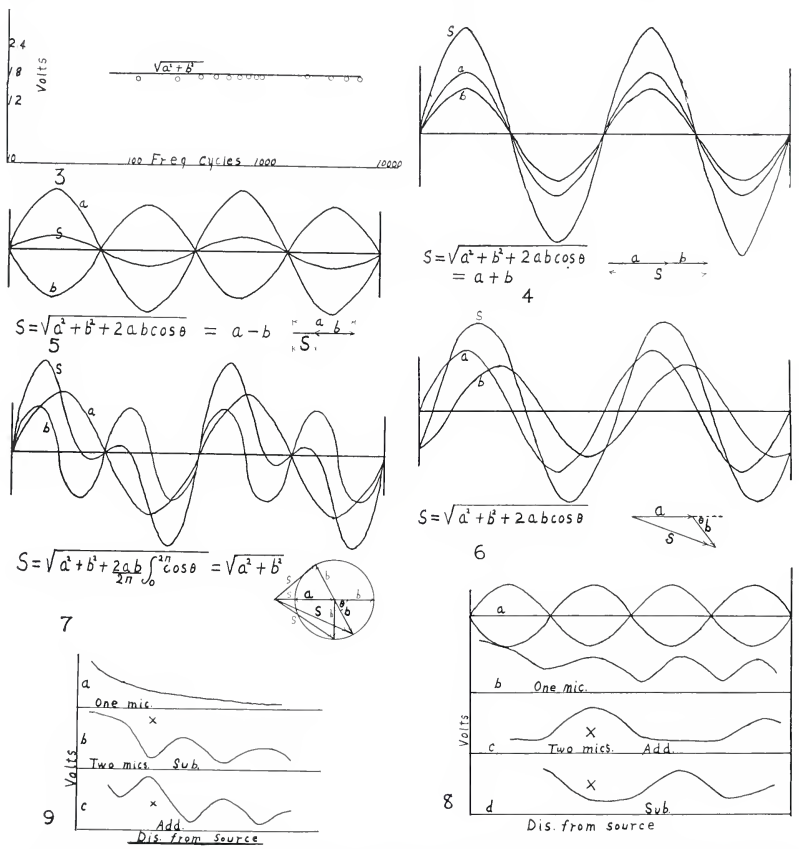
Figure 6 shows two waves of the same frequency, but b lagging a by Θ degrees. The familiar vector addition of two voltages out of phase gives

$$S = \sqrt{a^2 + b^2 + 2\,ab \cos \Theta}$$

which fits the general equation since cos Θ is constant. Figure 7 shows two waves of different frequencies added. In this case cos Θ varies from zero to unity through a period containing an integral number of cycles of both waves so the average value of cos Θ is zero and the general equation reduces to

$$S = \sqrt{a^2+b^2}$$

Each of the above cases was verified experimentally. The sum of two waves in phase and out of phase was measured by adjusting the two frequencies as nearly equal as possible and then watching the needle



Figs. 3-9. Fig. 3. The sum of the voltages from a fixed and a variable frequency. Fig. 4. The sum of two waves of the same frequency and phase. Fig. 5. The sum of two waves of the same frequency, but 180° out of phase. Fig. 6. The sum of two waves of the same frequency, but with 60° phase angle between them. Fig. 7. The sum of two frequencies, one double the other. Fig. 8. Measurements of sound intensity along the standing waves set up between the source and a wall: *a*, measurements with one microphone; *b*, with two microphones in series, one fixed, the other moved; *c*, with the microphones connected subtractive. Fig. 9. Measurements of sound intensity taken in open air without reflection: *a*, measurements with one miscrophone; *b*, with two microphones in series subtractive, one fixed at the cross, one moveable; *c*, with the microphones connected additive.

of the vacuum tube voltmeter swing to maximum and to minimum with slow beats. The maximum reading was the sum of the two waves in phase and the minimum reading was the sum of the two, 180 degrees out of phase.

It was impossible to hold the two frequencies constant enough to check their sum with a constant phase difference between them; so a method was devised to check this case which led to some interesting results. Two ribbon microphones were connected in series. The two microphones were placed in line from a sound source, and, by varying the distance between them, one could add the output from the two microphones from the same sound source, and hence of the same frequency, but with any desired phase difference.

Figure 8 illustrates the use of two microphones in series. Curve *a* is a representation of the standing waves set up between a sound source and a reflecting wall. Curve *b* is the measured intensity from a single microphone moved out from the sound source. The maxima and minima of intensity follow at each half wave length, the maxima being located at the velocity loops and minima at the nodes. Curve *c* shows the result of putting two microphones in series, keeping one fixed at the position marked X and moving the other along the direction of propagation. The maxima now follow at full wave lengths, showing that each successive half wave loop of the standing waves is out of phase by 180° with the one preceeding it. Curve *d* is the result of reversing the connections to one microphone. They are now connected subtractive and will give a maximum reading when they are situated in parts of the standing wave which are 180° out of phase.

Figure 9 shows the results of measurements in the open air where reflections are absent. Curve *a* is the intensity obtained by moving a single microphone away from a source of sound. Curve *b* was taken with two microphones in series subtractive, one at the fixed location the other moved out along the axis of propagation. This shows gradually decreasing maxima and minima at distances of a full wave length. Curve *c* is a repetition with the microphones connected additive.

It will be noted that this gives us a method of measuring the wave length of sound without the aid of standing waves. It is believed that this method of measuring wave length, and hence sound velocity, has not been used before.

Instead of using a constant frequency and moving the microphones apart to locate a wave length. the microphones may be located a fixed distance apart and the frequency varied until a maximum output reading is reached.

Discharge of Electricity from the Leaves of Forest Trees

GAYLORD S. KURTZ, Fort Wayne

A recent textbook on physics states that beech trees are seldom struck by lighting because of the large number of points on the leaves. This statement, made to illustrate the effect of points on the discharge of electricity, was challenged on the grounds that it was not based on proven facts. As a result of the challenge, it was suggested that I investigate the discharge of electricy from the leaves of forest trees. The subject "where lightning strikes" has been of interest to many people. It has been noted that forest trees are favorite targets for lightning and that certain kinds of trees are more often struck than others. A three-year census made by S. T. E. Dark, of the South London Botanical Institute, showed that the trees most often struck were, in order of frequency, oaks, elms, pines, poplar, willow, and ash.[1] He did not have record of a single beech, birch, horse chestnut, or holly tree that was struck.

In another survey, made by the government of Belgium, it was found that of eleven hundred trees struck 55% were poplar, 14% oak, 7% elm, and 7% conifers. In connection with the fact that isolated trees were most often injured it was stated: "In large forests of deciduous trees with fleshy leaves lightning strokes are prevented by a continuous interchange between the usually positive electricity of the air and the usually negative electricity of the earth. The stratum of air immediately over the trees is saturated with water vapor and is made conductive by evaporation from the leaves."[2]

These results are not in exact agreement, and this problem presented itself to me in the form of four questions:

1. Is the rate of discharge of electricity from leaves different for different trees?
2. Can these rates of discharge be compared by scientific methods?
3. Is there any relation between the rate of discharge and the structure of the leaf?
4. Can the resistance of the stems of different trees be compared by scientific methods?

The trees selected for experiment are representative Indiana species and may be divided into three groups: (1) trees with fleshy leaves, as the beech and the maple; (2) trees with dark green rather dry leaves, as the poplar and the oak; and (3) the conifers.

The plan of the experiment was to supply a high potential to an area of leaf surface equivalent to fifty beech leaves and measure the rate of discharge in milli-amperes. In like manner the high voltage was applied to a section of stem of given length and cross section and the current flow measured.

The high potential was supplied by a large type Wimhurst static machine, having four revolving mica plates each thirty inches in di-

[1]Dark, S. T. E., 1935. Where lightning strikes. Time, March 25.
[2]Anon., 1908. Liability of various trees to lightning stroke. Sci. Amer. Suppl. 66:187-188.

ameter, separated by two stationary plates of hard rubber. The plates were rotated by a variable speed direct-current motor and were inclosed in a glass case to keep out dust and moisture. The charge was collected on insulated combs and stored in Leyden jars. This machine gave a six-inch spark between spheres, three-fourths of an inch in diameter.

The difference of potential was 180,000 volts. This was measured by an electrostatic voltmeter made by mounting a copper sheet electroscope in a five gallon oil container. A sheet ⅛x8 inches was hinged at the top to a copper plate 1x9 inches, and the whole insulated from the container with cake sulphur. The plate and the hinged strip, having a like charge, repelled each other, and the amount of deflection, observed through a window, measured the difference of potential. Readings were accurate to a tenth of a unit, and a mirror under the scale eliminated reading errors.

The current was measured by a 110-volt D. C. voltmeter in series. A large Leyden jar condenser was placed in parallel with the voltmeter to steady the current flow and to prevent change of polarity. A steel plate 36 inches square was used for a ground. The leaves were fastened to cross wires on a wooden frame 24 inches square and the distance between the frame and the ground was varied so that the tips of the different leaves were the same distance from the ground.

The resistance of the branches was compared by the same method. An air-gap resistance was placed in series with the branches to raise the resistance to a point where the static machine would build up the required potential.

Data derived from the experiment are based on averages taken from readings on five different days. The readings checked consistently on the different days, and the results give a good basis for comparison. The voltage applied to the leaves was determined from a voltmeter calibration graph, and the current was read in milli-amperes. The resistance was determined by applying Ohm's law, $R=E/I \times 1000$ ohms.

The tree having the least resistance was the jack pine. The applied voltage was 25,000 volts, the current 8.0, and the resistance 3,125,000 ohms. The trees arranged in order from the least to the highest resistance are: jack pine, sugar maple, beech, white ash, dogwood, white pine, white oak, tulip poplar, spruce, black willow, white elm, black walnut, shag-bark hickory, sycamore, Carolina poplar, honey locust, and hemlock. The readings for the hemlock were: applied voltage, 35,500; current, 5.8 milli-amperes; and resistance, 6,125,000 ohms. This resistance is practically twice that of the jack pine. The other trees were distributed rather evenly between these two limits.

The resistance of the stems was compared in a similar manner. The shag-bark hickory had the least resistance, 1,460,000 ohms, and the Carolina poplar the greatest, 2,250,000 ohms. The trees arranged in order are: shag-bark hickory, jack pine, sugar maple, hemlock, spruce, black walnut, white pine, white elm, sycamore, honey locust, white ash, tulip poplar, beech, dogwood, black willow, white oak, and Carolina poplar.

There is probably some relation between the rate of discharge and the number of points on the leaf, but this is not proven by this experiment. For example, the jack pine and the beech have many points and

discharge well, while the spruce and the white elm have many points and discharge poorly. Also the sugar maple discharges as well as the beech but has only one-third as many points. The rate of discharge depends more upon the amount of moisture in the leaf than upon the shape. For example, the resistance of the sycamore leaves as given in the table was 4,810,000 but the resistance of the same leaves after drying on the frame over night was 6,040,000.

In the data found for the resistance of the branches, the amount of moisture again seems to be the controlling factor, because the size of the branch did not affect the resistance very much. The experiment does not show a definite relation between the specific gravity and the resistance.

The ideal condition for the tree to escape lightning strokes is for it to have a high stem resistance and a low leaf resistance. This prevents the charge from going to the leaves, and allows any charge that reaches the leaves to leak off. Considering these factors, the following trees are most likely to be struck: white elm, black walnut, shag-bark hickory, sycamore, Carolina poplar, honey locust, and hemlock. The following trees are least likely to be struck by lightning: beech, maple, white ash, dogwood, white pine, white oak, and tulip poplar.

My findings do not agree exactly with the results of the above mentioned surveys of lightning-struck trees, but there is a close correlation. It is an observed fact that the beech, maple, ash, and pine are seldom struck, while the walnut, sycamore, poplar, locust, and oak are the most likely to be struck. The observed facts are influenced by whether or not the tree stands in an isolated position.

Wave Velocity
(Abstract)

A. L. Foley, Indiana University

It will be recalled that Newton's original equation for the velocity of wave motion, $V=\sqrt{\frac{E}{D}}$, when applied to the atmosphere, gave a result roughly 20% too low. One of the early attempts to explain the discrepancy was the assumption that in any particular path through the atmosphere the molecules themselves occupy about one-sixth the distance and that sound is transmitted through them at a very much greater velocity than through the space between them. Speculation ceased when Laplace called attention to the fact that the formula gives very good results if one uses the adiabatic instead of the isothermal elasticity in applying it. The general agreement between the velocities obtained experimentally and those given by the corrected Newtonian equation was so good that scientists considered the question to be finally settled and paid little or no attention to anyone proposing a different solution.

The writer confesses that he cannot understand the demand for adiabatic elasticity in the case of a very weak sound wave, one in which the amplitude of molecular motion is but a fraction of the diameter of the molecule (some authorities say as little as 1/30 of that diameter) in a gas with molecular distances many, many times the molecular diameters. Is it possible that the Laplace-Newton equation is not the last word on the subject? At any rate, it is not the *only* word. In 1860 Earnshaw[1] proposed a solution which, unlike Newton's, demands a variation in sound wave velocity with changes in pitch and intensity. This is in direct contradiction to the usual text book statements that the velocity of sound in the atmosphere is independent of barometric pressure, pitch, and intensity. To be sure, some texts qualify the latter point by saying "independent of intensity except for sounds of very great intensity at points near the source." Many attribute a greater velocity near the source to a mass motion of the air near the source, as is known to be produced sometimes, for instance, when a cannon is fired. But, so far as the writer knows, rarely has the question been raised as to the equality of the velocities of waves of moderate and of low intensity. In discussing the question Earnshaw says:

"With respect to the velocity of sound, which has hitherto been found experimentally to exceed the velocity obtained by theory, it is shown that the value obtained by approximative methods is the minimum limit of sound velocity, so that the actual velocity will always be greater, the excess depending upon the intensity and genesis of the sound. It is shown that all the parts of a wave do not travel at the same rate,—a circumstance which leads to the formation of a bore in the front of the wave. Several previously unexplained phenomena, which have been recorded by different experimentalists, such as double reports of fire-arms heard at a great distance, the outrunning of one sound by another observed by Capt. Parry, the comparative powers of different gases of transmitting sounds, and the laws of transmission of sound from one medium to another, are accounted for in this paper, and directly deduced from the integral of the equation of wave-motion.

[1]Earnshaw, Samuel, 1860. On a new theoretical determination of the velocity of sound. Phil. Mag. 19:449; 20:37, 186. Abstract, Proc. Roy. Soc. 9:590, 1857-59.

"The error committed in calculating the velocity of sound, was not the leaving out the consideration of the development of heat, but the supposing the medium of air to be *continuous*. I am surprised to find the result so much affected by a circumstance which appears trifling,—and the more so, as the radius of the sphere of sensible molecular action is known to be, though finite, very small. The assumption of continuity is therefore by no means so allowable as we should be inclined *a priori* to supose; and its effect on the motion of an elastic medium is very much greater than was to be expected." (Sheffield, May 9, 1860.)

Regnault[2] appears to have been the first to make any extended experiments on the question of the velocity of sound at different distances from the source, which, of course, means measurements at different sound intensities. In 1864 Regnault announced that he had found the average velocity of the sound produced by firing a cannon to be a little more than 0.2% greater over a distance of 1280 meters from the source than when measured over a distance 2445 meters from the source.

Space will not permit even naming all those who have experimented on this question. It is significant, however, that all agree on the statement that sound velocities *do* depend upon sound intensities. In 1889 Threlfall and Adair measured the velocity of sound in water. The calculated velocity was about 1500 meters per second, while the observed velocity was 1732 meters per second when the sound was produced by firing a charge of 9 ounces of gun cotton, increasing to 2013 meters per second when the charge was increased to 64 ounces. The author of this paper, using a photographic method that enabled him to determine the *instantaneous* velocity of the sound produced by an electric spark,[3] found the velocity to be more than three times as great at a distance of 3.4 mm. from the spark as it was at a distance of 34 cm., 100 times as far from the spark.

The coming spring and summer the writer expects to study the question further (making use of a sound-ranging outfit loaned him by the United States Government), to determine, as accurately as the method will permit, the relation between sound velocity and intensity.

The assumption that Newton's equation demands a constant velocity for all intensities tacitly assumes that the elastic coefficient of a medium is independent of the strain so long as the strain is well below the elastic limit. The writer has under way an experiment to test the accuracy of this assumption for very small displacements. To the writer the interest attaching to the problem comes from a possible inference that may be drawn respecting the velocity of light waves of very low intensity. It is admitted at once that conclusions arrived at from a study of wave velocities in material media may not apply at all to light waves in the ether. On the other hand it is to be said that the application of Newton's equation to the ether has resulted in several verifiable deductions.

Really, why should we assume that the velocity of light waves (photons, corpuscles, or what have you) when they left the source millions of years ago, is the same as it is now when their energy is so small that it must be condensed by exceedingly large mirrors or lenses

[2]Regnault, V., 1868. Mem. de l'Acad. Pair **37**:1, 3. Compt. Rend., **66**:209. Phil. Mag. Ser. 4, **35**:161, 1868.
[3]Foley, Arthur L., Phys. Rev., N. S., **16**:449-463.

and integrated over a period of several hours or days in order to make any impression on a sensitive photographic plate. But this is precisely what is assumed by those who, finding a minute shift of the spectral lines toward the red, conclude that our universe is expanding. It is assumed, likewise, by those who would explain the shift as due to a gravitational attraction for radiation. The writer does not presume to pass upon either of these theories. However, he would call attention to the fact that it is highly improbable that the shift is due to both causes. One or the other of the two hypotheses must be rejected; possibly, on the results of further studies, both of them may be discarded. At this time the writer regards them as hypotheses only, hpyotheses that must await the future for verification or rejection.

A Cold Cathode Rectifier

CHAS. T. KNIPP, University of Illinois

The cold cathode rectifier presented at the Science Exhibit sponsored by the A.A.A.S. at St. Louis last holidays, and in May, 1936, before the physics section of the Illinois Academy of Science, at Quincy, Illinois, has been very much improved as an efficient device for the rectification of comparatively high alternating voltages. The rectifier makes use of Hittorf's principle of limiting the development of Crookes' dark space. As made at this writing (Nov. 6, 1936), with electrodes of about 10 sq. cm. each, the rectifier transmits 30 ma. on half wave rectification, and about 50 ma. on full wave rectification. This is for 25,000 alternating volts.

The set-up in complete form is shown in Figure 1. There are four essential parts: (1) a 50,000 volt transformer (Thordarson) with a split grounded secondary (Two 25,000 volt transformers in parallel will answer.); (2) a cold cathode rectifier with its three special electrodes; (3) a large-diametered discharge tube MM, styled the load; and (4) a 5-inch DuMont oscillograph. (This item in the present demonstration was omitted.)

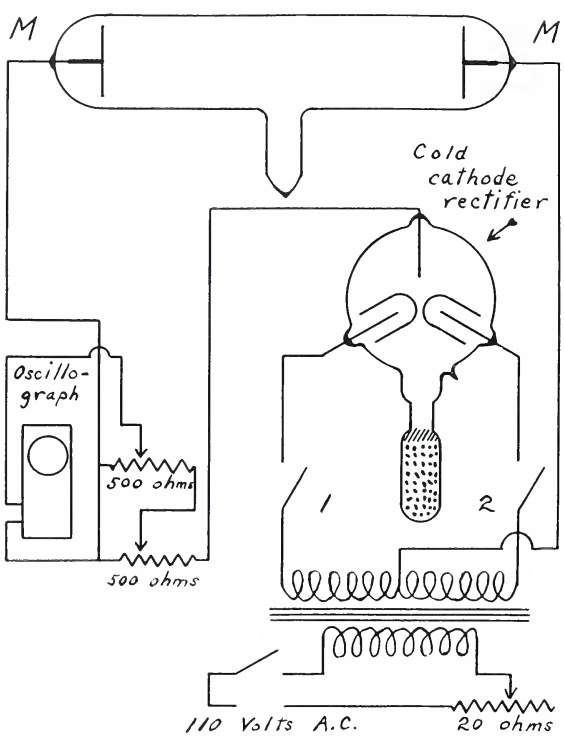


Fig. 1. Complete set-up for both half and full wave rectification.

In addition to these, rheostats and switches are needed as shown in the figure.

To operate, close the 110 volt switch to primary. Then with the vacuum in the rectifier in the Geissler stage (the vacuum is readily regulated to any degree by the charcoal-in-liquid-air control) close switch 1. The discharge in MM is alternating, i.e., either electrode is cathode and anode alternatingly. Now open switch 1 and close switch 2. The discharge through MM is the same as before but now passes through the right hooded electrode in the rectifier. Thus one gets an alternating discharge (25,000 volts) through MM on closing either switch 1 or switch 2. If next both switches are closed simultaneously, the discharge will not pass through MM, but rather through the rectifier from one hooded electrode to the other. The above phenomena are for a *low vacuum* in the rectifier.

Now for the rectifying action. By the charcoal-in-liquid-air control, the vacuum in the rectifier is *increased* (the gas pressure is reduced) until Crookes' dark space *extends beyond* the confines of the hood surrounding each of two electrodes (Fig. 1). When this stage is reached, the electrode that is hooded can serve as anode only; i.e., the current passes in one direction only. If now switch 1 is closed the discharge through MM shows distinct polarity—one end is anode and the other cathode. The unidirectional characteristics of the discharge are very distinct. On opening switch 1 and closing switch 2, the same characteristics, with polarity unchanged, appear in MM, but now, as above, the discharge passes through the right hooded electrode.

On closing both switches simultaneously the alternating discharges can no longer pass through the rectifier from hooded electrode to hooded electrode (because of the extended Crookes' dark space) and are forced to pass through MM as full wave rectification. That nearly twice the energy (in milliamperes) now passes through MM is evinced by the discharge through it becoming distinctly brighter. Thus a cold cathode may be employed in the rectification of a high potential alternating current.

The above phenomena were demonstrated during the presentation of this paper.

PROGRAM OF THE SECTION ON PSYCHOLOGY

Chairman: EDMUND S. CONKLIN, Indiana University

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1. Memory for visual, auditory and visual-auditory material. Frank R. Elliott, Indiana University.
2. Family adjustment influences in the neuroticism score. Edmund S. Conklin, Indiana University.
3. The distribution of action potentials during imaging. William A. Shaw, Indiana University.
4. A summary of the psychologists' work at the Indiana Girl's School, with suggestions for enlarged departmental service. Virginia Hetherington, Indianapolis.

Dr. P. R. Hightower, of Central Normal College, was elected chairman of the section for 1937.

Memory for Visual, Auditory, and Visual-Auditory Material

Frank R. Elliott, Indiana University

The rapid advance of radio and the growing promise of television lend renewed interest to the question of the relative efficiency of visual, auditory, and visual-auditory materials in the memory and learning process. The question is one which has an immediate practical interest for educators and advertisers, since they are constantly using both modes of communication to their students and their buyers. The question is one which has had repeated attention from[1] psychologists since the early visual-auditory experiments of Münsterberg and Bigham in 1892-3 at Harvard.

The present laboratory experiment is the outgrowth of a series of field investigations with several thousand subjects in the life situation. In one series it was observed that 30,277 Indiana high school seniors made the inquiry response, in proportion to numbers stimulated, about five times as often when they were provided literature and a speaker as when they were provided only literature. Likewise, about two and one-half times as many students made the enrollment response when furnished literature and speaker as when furnished merely literature. Another series of field studies showed that about 27,000 Indiana State Fair visitors gave attention to an exhibit in the following percentages: When the exhibit was accompanied by no explanatory advertising, 19.9%; when presented with poster advertisement, 25.4%; when shown with the same advertising presented by radio loud speaker, 32.1%; and when shown with poster and radio advertising simultaneously, 33.4%. Memory tests with 179 subjects showed least memory for details of the exhibit with the poster presentation and approximately the same memory with either the radio or the combined poster-radio types of presentation.

The problem was transferred in 1935 to the psychology laboratories of Columbia University for a laboratory check on the field results. Thirty-six short fictitious advertisements were prepared, of which the two following advertisements are examples:

RESTWELL MATTRESS

For the rest of your life. All tired out? Needing a perfect night's rest? Then go to bed on a *Restwell Mattress.*

POLAND LAMPS

For your home. You will have to see these new lamps to appreciate them. See our new line of *Poland Lamps.*

[1]A historical survey will be found in the following reference: Elliott, Frank R. Memory for Visual, Auditory and Visual-Auditory Material. Arch. Psychol. No. 199. 1936.

These advertisements were presented in rotation by three modes: (1) on a screen, (2) by radio, and (3) by screen and radio simultaneously. To equalize position advantages, practice effects, association values of materials, and memory capacity of the subjects, the following rotation order of presentation was observed:

Sets of Advs.	Subjects of Section I	Subjects of Section II	Subjects of Section III
Nos. 1-12	Visual	Auditory	Vis-Aud.
Nos. 13-24	Auditory	Vis.-Aud.	Visual
Nos. 25-36	Vis.-Aud.	Visual	Auditory

The subjects were asked to classify each advertisement as descriptive or non-descriptive, depending upon whether or not the trade name described the product and the body was descriptive of it. Restwell Mattress, for instance, was regarded as a descriptive advertisement and Poland Lamps a non-descriptive advertisement. The purpose of this classification was (1) to separate the 36 advertisements into two groups for comparative purposes later, and (2) to mask the memory tests which followed.

The tests were for recall and recognition. In the recall test, the commodity name was presented and the subject was asked to fill in on a score sheet the appropriate trade name. In recognition, the subject

TABLE I. COMPARISON OF MODES
(Composite of Recall and Recognition)

Superiority of Mode	TEST SITUATIONS*			
	No. 1	No. 2	No. 3	No. 4
Auditory Surpasses Visual	24.9%	12.3%	23.6%	5.0%
Chances in 100 of a Reliable Diff.	100	99.4	99.9	79
Vis.-Aud. Surpasses Visual	41.0%	24.6%	36.5%	25.0%
Chances in 100 of a Reliable Diff.	100	100	100	100
Vis.-Aud. Surpasses Auditory	12.9%	13.3%	10.4%	16%
Chances in 100 of a Reliable Diff.	100	100	96	100

*The test situations were as follows: No. 1—all of Group X and Sections 1 and 3 of Group Y, with section 2 eliminated due to faulty experimental conditions; No. 2—All of Group X and Group Y; No. 3—Group X only (non-college); No. 4—Group Y only (college).

was asked to identify the real trade names in a list of 36 real and 36 fictitious names.

Two groups participated in the tests: Group X—made up of 67 federal relief workers in New York City, 38 men and 29 women, which is referred to as the non-college group since none of them were in college at the time of the test; and Group Y—consisting of 76 Columbia University Extension class students, 38 men and 38 women, which will be referred to as the college group. Members of Group Y averaged about 22½ years of age, while members of Group X were a little more than ten years older.

From the foregoing general information, it will be noted that these tests offered four bases of comparison: (1) comparison of modes, (2) comparison of groups, (3) comparison of sexes, and (4) comparison of materials (descriptive vs. non-descriptive advertisements). A brief summary of results, which may be noted in full detail from the author's monograph in the Archives of Psychology, is shown in Table I.

This table shows the percentage by which the average score following one mode surpassed the average score following the other modes. The indication is that visual presentation always resulted in a lower memory score than either auditory or visual-auditory mode produced. Visual-auditory presentation brought the highest score, auditory the next highest, and visual the lowest in each one of the four groupings of data. In all but one case, the reliability of the differences was high.

TABLE II. COMPARISON OF GROUPS
(Composite of Recall and Recognition)

Comparison	Visual Av.	Auditory Av.	Vis.-Aud. Av.
Group Y (College)	13.66	14.34	17.08
Group X (Non-College)	10.01	12.37	13.66
Diff. in Favor Group Y	3.65	1.97	3.42
Percent Diff. in Favor Group Y	36%	16%	25%

From Table II it will be seen that the college group always surpassed the non-college group in memory for each mode and that this advantage was highest for visual mode and lowest for auditory mode. Stated another way, this means that the non-college group responded better by auditory mode than by visual mode. Note from Table I that the auditory average was 12.37, as compared with a visual average of 10.01 for the non-college group; and that the difference was much less in the college group, namely, auditory 14.34 vs. visual 13.66.

The college group was less variable by each mode than the non-college group, thus indicating a more consistent performance than the non-college group demonstrated. Likewise, the college group guessed

less in the recognition test than the non-college group, as shown by score reductions when the crude recognition scores were corrected for guessing.

TABLE III. COMPARISON OF SEXES

(Composite of Corrected Recognition and Recall)

Comparison	Women (Groups X and Y)		Men (Groups X and Y)	
Aud. Av.	12.80		14.16	
Vis. Av.	10.06		13.68	
Diff. by Which Aud. Surpasses Vis.	2.74	(27.2%)	.48	(3.5%)
D/Sigma D; Chances in 100 of Real Diff.	3.28	(100)	.64	(74)
Vis.-Aud. Av.	15.70		15.79	
Vis. Av.	10.06		13.68	
Diff. by Which Vis.-Aud. Surpasses Vis.	5.64	(56.1%)	2.11	(15.4%)
D/Sigma D; Chances in 100 of Real Diff.	8.57	(100)	2.88	(99.8)
Vis.-Aud. Av.	15.70		15.79	
Aud. Av.	12.80		14.16	
Diff. by Which Vis.-Aud. Surpasses Aud.	2.90	(22.7%)	1.63	(11.5%)
D/Sigma D; Chances in 100 of Real Diff.	3.69	(100)	2.44	(99.3)

It will be noted first that men somewhat excel women in memory scores, a result contrary to the general finding but similar to that of Dietze.[2] A more important observation for the present study is that women show a far greater advantage for auditory over visual mode and visual-auditory over visual mode than do men.

Another finding is that women are less variable than men for auditory and visual-auditory modes but more variable than men for visual mode. Further, women are shown, in the detailed analysis of data not permissible here, to do more guessing than men, particularly following visual presentation.

One measure of the difficulty of material is the frequency with which it is remembered. On this basis, Table IV shows that for all modes descriptive trade names were 5.7 times as easy to recall as non-descriptive trade names, and particularly easy by the auditory mode; i.e., a ratio as high as 10.07 to 1 in favor of descriptive material. This is another way of saying that it is harder to remember the more difficult material, the non-descriptive trade names, by radio than by screen.

[2]Dietze, Alfred G., 1932. Some sex differences in factual memory. Amer. Jour. Psychol., 44:319-321.

This finding appears to justify the efforts of radio program managers to keep their material simple and easy to comprehend. Radio is not the medium for involved, academic, difficult material.

TABLE IV. COMPARISON OF MATERIALS

(Comparison of Descriptive vs. Non-Descriptive Trade Names by Method of Frequency Ratios)

RATIO OF RECALL FREQUENCY; DESCRIPTIVE TO NON-DESCRIPTIVE NAMES

Group	Visual Mode	Aud. Mode	Vis.-Aud. Mode	All Modes
Group X	6.01 to 1	10.07 to 1	5.28 to 1	
Group Y	4.30 to 1	7.15 to 1	4.59 to 1	
Both	4.88 to 1	8.12 to 1	4.84 to 1	5.70 to 1

RATIO OF RECOGNITION FREQUENCY; DESCRIPTIVE TO NON-DESC. NAMES

Group	Visual Mode	Aud. Mode	Vis.-Aud. Mode	All Modes
Group X	1.27 to 1	1.18 to 1	1.26 to 1	
Group Y	1.42 to 1	1.22 to 1	1.26 to 1	
Both	1.32 to 1	1.20 to 1	1.26 to 1	1.26 to 1

Another deduction from the above comparison is that descriptive material has an advantage over non-descriptive material, particularly for the less schooled population of Group X and for the radio mode.

It will be noted that the ratio of descriptive to non-descriptive trade names is not high (1.26 to 1) in the recognition tests, obviously due to the ease of recognition compared with that of recall.

Summary and Conclusions

In summarizing the results of this study, the conclusion is reached that it provides a laboratory verification of the author's field studies ranking modes of presentation in the following order: most efficient, visual-auditory; next in efficiency, auditory; and least effective, visual.

Group comparisons show that the college group excelled in amount of material remembered by any mode and that this advantage was highest for visual and lowest for auditory mode.

Sex comparisons show that women demonstrated a far greater advantage for auditory over visual mode than did men, though both men and women remembered more by the auditory mode than by the visual mode. The visual-auditory mode resulted uniformly in the highest scores for both men and women.

Comparison of materials shows that descriptive trade names were recalled between five and six times as frequently as non-descriptive trade names and that descriptive names lent themselves particularly well to auditory presentation; the frequency ratio in favor of descriptive names was highest by auditory mode, and higher for the less schooled population of the non-college group than for the college group.

The general excellence of visual-auditory mode may be explained on the ground of summation of stimuli, facilitation, intersensory heightening effects through the simultaneous stimulation of two receptor systems, improved clarity, and certainty of reception.

The superiority of auditory over visual mode may be explained on the basis of (1) the non-directional character of sound which permits clear reception without the direct fixation required in vision; (2) the social significance which the sound of the human voice has in comparison with the "coldness" of type and other visual materials; (3) undisturbed repetition of the trade name when presented orally as compared with conflicting elements of the body of advertising copy presented on the screen, and (4) the role of habituation to increasing auditory stimulation through the nation's radio sets for 78,000,000 people through the 60,000 public address systems in the schools, and through the millions of hours spent annually at sound movies.

The author advances the hypothesis of *visual-auditory shift* to explain the results of DeWick, Wilke, Stanton, Cantril, Carver, Allport, and the present writer, generally showing an advantage for auditory over visual mode and thus reversing the general trend of experimental results prior to 1930 in favor of visual mode. The author's theory is that a shift may be taking place from visual to auditory dominance. Such shifts take place in children, as Löwenfeld and Hetzer and others have demonstrated; children remember better that which they hear up to the age of eight or ten years, when they acquire the reading habit; after that they remember better what they read. Why cannot a similar shift take place in the adult; why cannot he change from visual to auditory dominance, since there has been such an enormous increase of listening during the years since the advent of radio, public address systems, and sound films?

Two findings in the present studies tend to support the *visual-auditory shift* hypothesis. One is that women show a greater advantage for auditory over visual mode than men, which is what could be expected from the theory, in view of the fact that surveys have shown that women listen to radio about 22% more than men. Another finding is that non-college people do much better by auditory mode compared with visual mode than college subjects; this is in line with surveys showing that non-college people listen more than twice as much to radio as college people. Habituation to auditory mode may be the explanation. Capacity to adapt to changed environment is everywhere evident in life, and this may be the cause of our recent findings in favor of auditory over visual mode in apparent contradiction to the results of most experimenters prior to 1930.[3]

[3]For detailed references to surveys and results cited here, see the author's previously mentioned monograph in the Archives of Psychology, No. 199.

Family Adjustment Influences in the Neuroticism Score

Edmund S. Conklin, Indiana University

In his first presentation of the Personality Schedule, Thurstone reported the isolation for special examination of the 19 questions on family relationships which appear in the schedule. He compared the responses to those questions by the fifty persons giving the highest neuroticism scores with the responses of the fifty persons giving the lowest neuroticism scores. With the exception of one question all of these showed a markedly greater frequency of significant answers in the group having high neuroticism scores.

Since that time I have developed a diagnostic scoring scheme for the personality schedule which makes it possible to score the schedule in three other ways than that proposed by Thurstone. These diagnostic scorings reveal general tendencies toward an abnormality of personality pattern, tendencies toward a psychotic type of personality pattern, and tendencies toward a definitely schizoid type of personality pattern. It seemed, therefore, wise, and possibly instructive, to isolate again the reactions to the nineteen questions concerning family relations In doing so I sought to answer this question: Do persons who answer the family relations questions significantly manifest scores for abnormality, for psychotic trend, and for schizoid trend that are higher on the average than for those persons who do not manifest family troubles?

My procedure was to obtain the average score on each of the diagnostic patterns for all persons answering the first family relations question significantly and to place beside it the average score on each of the diagnostic patterns for those answering the question insignificantly. Then this same thing was done for each of the remaining questions on family relations. By this means I had before me a list of the means (arranged by questions) which could be treated as a distribution of scores for those answering the family-relations questions significantly and another list for those answering insignificantly. This I did, obtaining, of course, the mean and the sigma of the mean in order to obtain the significances of the differences. There may be some possibility of question concerning the propriety of this statistical procedure. Nevertheless, it does express simply and clearly what anyone who reads the columns of figures will perceive is definitely present in them.

All this was first done on a group of 100 unselected college students, mostly sophomores. The figures in Table I indicate the results:

Table I. Answers of 100 Students

	Significant Answers	Insignificant Answers	Critical Ratio
Abnormal Scoring	22.46	13.35	10.1
Psychotic Scoring	26.03	19.8	6.3
Schizoid Scoring	25.20	18.4	13.2

Obviously those students who admit family difficulties manifest much greater tendency toward abnormalities of personality pattern than do those who appear to lack the family relation troubles. But it should also be observed that no causal relation is demonstrated here. Perhaps the abnormality twist of the personality pattern is the product of family maladjustment, as so many studies of delinquency in recent years have indicated; but it is also possible that the family maladjustment is the product of a personality which does not adapt well to family life.

I also had at my disposal a large amount of data acquired from diagnosed pathological cases. I had, already tabulated, the individual responses to each of the questions by a group of 34 psychoneurotic cases, a group of 52 manic-depressive cases, and another group of 78 schizophrenic cases. So it seemed possibly instructive to treat the responses of these pathological cases in the same fashion as I have just described for the student group. The following tables are the consequence (Tables II-IV):

TABLE II. PSYCHONEUROTIC CASES

	Significant Answers	Insignificant Answers	Critical Ratio
Abnormal Scoring	23.32*	26.13*	2.3
Psychotic Scoring	14.03	14.67	0.85
Schizoid Scoring	18.95	18.23	0.83

TABLE III. MANIC-DEPRESSIVE CASES.

	Significant Answers	Insignificant Answers	Critical Ratio
Abnormal Scoring	34.62	28.15	3.87
Psychotic Scoring	36.87	29.57	5.93
Schizoid Scoring	26.47	18.79	5.53

*Note the lower average for the persons answering significantly.

One most unexpected result of this comparison appears in the table for the psychoneurotic cases. There it will be observed that the psychoneurotics admitting family troubles do not give significantly higher scores than those who do not. Apparently psychoneurotics may or may not have family troubles with little significance in these scores, or, they may be more astute in lying, or they may have more reason for lying, or what not. It is still more curious that on the abnormal scoring the psychoneurotics who reported family troubles actually gave a lower

TABLE IV. SCHIZOPHRENE CASES.

	Significant Answers	Insignificant Answers	Critical Ratio
Abnormal Scoring	38.72	28.30	6.35
Psychotic Scoring	41.07	32.13	5.66
Schizoid Scoring	43.12	34.29	9.01

average score than those who denied family troubles. And the difference is fairly significant (critical ratio of 2.3).

The tables for the manic-depressive cases and for the schizophrenes run about as one would expect. In both groups those answering the family-relations questions significantly give much higher scores on all forms of the diagnostic scoring device than do those who answer these questions indicating little or no trouble in their family relations. Apparently the psychotic cases having family-relations troubles are those with personality patterns distorted far more in the direction of psychosis and of schizophrenia. Again the question of cause and effect could be raised, but there is no use in raising it because I cannot answer it.

Thus it seems quite certain that the questions in the Thurstone personality schedule on family relations are very important. But there are only 19 of them—too few, probably, for a diagnostic scoring which would be reliable; and a reading of them reveals that many kinds of family trouble are not included. Therefore, the scoring of any person for the degree of his family adjustment or maladjustment at present in terms of these 19 questions is scarcely practicable, important as family relations appear to be in maladjustment distortions of personality. If a score for family adjustment could be obtained, the possibilities of usefulness quickly exhaust almost anyone's capacity to imagine. Probably such could be developed by much the same procedure as that originally used by Thurstone in the development of his personality schedule.

PROGRAM OF THE SECTION ON ZOOLOGY

Chairman: B. E. MONTGOMERY, Purdue University

1. Records of Indiana Dragonflies 1X, 1935-1936, with notes on the distribution of the genera Anax, Celithemis, and Erythrodiplox in the United States. B. Elwood Montgomery, Purdue University.
2. Oviposition of Perithemis (Odonata, Libellulidae). B. Elwood Montgomery, Purdue University.
3. A comparative study of the zona pellucida of the mammalian ovum. Blanche E. Foglesong, Indiana University.
4. The absorption of colloidal carbon from the body cavity of the Ammocoetes. Theodore W. Torrey, Indiana University.
5. The Cicadidae of Indiana (Homoptera). Howard O. Deay and George E. Gould, Purdue University.
6. Skull of musk-ox, genus Symbos, from Montgomery County. Fred T. Hall, Crawfordsville, and M. W. Lyon, Jr., South Bend.
7. Notes on the internal anatomy of Canthon laevis Drury. Robert H. Cooper, Ball State Teachers College.
8. Inherited behaviour patterns in Drosophila. J. P. Scott, Wabash College.
9. Procedure in introductory zoology laboratory. E. G. Stanley Baker, Wabash College.
10. Phylogeny of the neurals and central plastral row in chelonians. Major Chapman Grant, U. S. A. Ret., San Diego, Cal.
11. The incidence of animal parasites in the common rat (Rattus norvegicus) in Tippecanoe County, Indiana. R. M. Cable and W. H. Headlee, Purdue University.
12. Staining methods for Protozoa. William P. Allyn, Indiana State Teachers College.
13. The status of human parasitic infections in Indiana. W. H. Headlee, Purdue University.
14. Studies on venomous snakes of Indiana. William P. Allyn, Indiana State Teachers College.
15. Additional observations on the salamanders of Putnam County and vicinity. Albert E. Reynolds, DePauw University.
16. The assimilated sediment in the Tippecanoe Lake. Ira T. Wilson, Heidelberg College, Tiffin, Ohio.
17. Insects of Indiana for 1936. J. J. Davis, Purdue University.

The following titles of papers published in this volume were received too late to be included in the published program of the meeting.

The "midventral keel" in Testudinata. Chapman Grant, San Diego, Cal.

Orthogenetic variation. Chapman Grant.

A new second intermediate host of the Trematode (Gorgodera amplicava). W. E. Martin, Purdue University.

Dr. W. P. Allyn, State Teachers College, was elected chairman of the section for 1937.

Records of Indiana Dragonflies, IX,[1] 1935-1936.

B. Elwood Montgomery, Purdue University

Very little attention was given to dragonfly collecting during 1934 and 1935 except for brief visits to roadside pools, ponds, streams, etc., along or near to principal highways, while making trips for other purposes. However, a total of 1667 specimens representing 64 species were secured and studied in the preparation of this report. Only the more interesting captures and new county records are listed here. Three species new to the state list (* starred in the list of species) are recorded, bringing the number of species of Odonata known from Indiana to 139.

In order to present the data in as concise form as possible, the collection numbers used in field notes are employed in recording the captures. A list of these numbers with complete information is first given and then these numbers are quoted, following the name of the county, instead of complete collection data in the list of species. The two first digits of each number indicate the year in which the collection was made (35—1935, 36—1936). Collections 3520 to 3533 inclusive, were made by A. W. Trippel, 3534 and 3535 by John M. Amos, and 3536 by C. C. Alexander; all other collections unless indicated otherwise were made by the author. Specimens obtained from collections made by Purdue University students as part of their class work are indicated by the initials "P. U."

All specimens, except those belonging to the genus Amphiagrion, which were studied by Mrs. Leonora K. Gloyd, were determined by the author.

List of Collection Numbers

355. Pond along state road 41, about one mile north of Rockville, June 5.

356. Small pond along state road 59, about five miles south of Brazil, June 6.

357. Pool along state road 41, about eight miles north of Morocco, June 17.

358. Small stream crossed by state road 15, four miles southeast of Wabash, June 18.

359. Pond along state road 26, about nine miles west of West Lafayette, July 6.

3510. Pond about three miles south of Pimento, July 8.

3511. Swamp-like ditches along roadside, about two miles south of Switz City, July 9.

3512. Small pond in pasture, three miles southeast of Linton, July 9.

3513. Same as 3510, July 9.

[1]The last previous paper in this series was published in 1935 (Proc. Ind. Acad. Sci., 44:231-235).

3515. Pond used as water supply reservoir by mine, Pimento, July 9.

3516. Same as 355, July 10.

3517. Small stream crossed by state road 55, about five miles south of Newton-Lake county line, July 11.

3518. Pools along state road 61, one mile east of Oakland City, August 23.

3519. Old water supply lake, Oakland City, August 23.

3520. Along state road 43, five miles south of Lafayette, June 7.

3521. In wheat field, one mile north of Americus, June 12.

3522. Little Wea Creek, about six miles southeast of Lafayette, June 21.

3523. Little Potato Creek, near Manson, June 25.

3524. Little Pine Creek, about one-half mile north of Montmorenci, June 28.

3526. Little Pine Creek at "High Bridge," near Green Hill, June 30.

3527. Eight miles east of Medaryville, July 4.

3528. Five miles north of Wolcott, July 4.

3529. Creek, two to four miles east of Aix, July 4.

3530. Eight miles east of Wabash, July 5.

3531. Same as 3529, July 6.

3532. Ten miles north of Wolcott, July 6.

3533. Same as 3529 and 3531, July 16-19.

3534. Lost River, about three to four miles southeast of Orleans, July 14.

3535. Same as 3534, July 16.

3536. Near Pulaski, June 12.

361. Schlamm Lake, Clark County State Forest near Henryville, June 8. Collected along south shore of lake, west from dam about one-third of circumference of lake.

362. Same as 361, June 9, 5:45-6:15 a. m. Very few Odonata moving at first—*Epicordulia princeps* patrolling the shore and some Zygoptera (Enallagma and Ischnura) stirring in the grass back from the lake. These latter gradually moved towards the shore line as the sun rose above the trees.

363. Francke Lake, Clark County State Forest near Henryville, June 9. Collected in the morning along the shore line for a few hundred feet in both directions from the pier.

364. Same as 363, June 9, afternoon.

365. Francke Lake, June 10.

366. Schlamm Lake, June 10, afternoon.

367. Schlamm Lake, June 11, morning.

368. Francke Lake, June 11, morning.

369. Francke Lake, June 11, afternoon.

3610. Schlamm Lake, June 11, afternoon.

3611. Stream flowing in edge of forest, then through an open area, Clark County State Forest, June 12, in mid-morning. In previous years, at this season the water in this stream has been reduced to frequent, small pools, with no flow (See: Proc. Ind. Acad. Sci. 41:452. 1932).

3612. Schlamm Lake, June 12, morning.

3613. Same as 3611, afternoon.

3614. Francke Lake, June 12, afternoon.

3615. Schlamm Lake, June 12, afternoon.

3616. City lakes, Huntingburg, June 13, 3:00-5:00 p. m.

3617. Pond about two and one-half miles north of Poseyville, June 14, 5:00-6:00 p. m.

3619. New water supply lake, Oakland City, June 15, 10:00 a. m.-12:30 p. m. Made a complete circuit of lake; many Odonata seen.

3620. Old water supply lake, Oakland City, June 15, 2:00-2:30. Too much wind; few Odonata flying.

3621. Freeman Lake, directly west of Patton, June 22. Collected during early afternoon for about a quarter of a mile along the shore line, including wooded hills and broad flat "meadows" just above the water level.

3622. Burnett's Creek and Wabash River, north of Lafayette, July 17. Collected during the morning from a point about a mile above the mouth of Burnett's Creek to the Wabash River, then south along the west bank of the river for about three miles.

3622A. Hoagland Ditch, along state road 43, about three miles south of Monon, July 18.

3623. Mud Creek along state road 25, about five miles south of Rochester, July 18.

3624. Rocky stream along state road 27, about four miles south of Richmond, August 11.

3625. Rocky stream, usually of considerable width and about one to 12 inches deep, but dry in places, along state road 44, about two miles east of Liberty, August 11.

3626. East fork of Whitewater River, just north of Brownsville, August 11. Water of varying depth, from a few inches in rocky rapids to several feet in other places; banks also varying—bluff, rocky, muddy, willow-margined, etc.

3627. Little Blue River, along state road 44, about three miles east of Shelbyville, August 12. Rocky, but with considerable water.

3628. Shawnee Creek (branch of Flat Rock River), about three miles north of Falmouth, August 13. A dredged drainage ditch.

3629. Hill's Branch along state road 9, about five miles south of Fountaintown, August 14. Small stream with mud bottom and grassy banks.

3630. Stoney Creek and adjacent pool along state road 32, near Lapel, August 18.

3631. Big Duck Creek (Small dredged drainage ditch) about five miles northeast of Elwood, August 19.

3631A. Gravel pit, about one and one-half miles southeast of Alexandria, August 19.

3632. Little Eagle Creek along state road 29, August 20. Rocky, but with large, mud-bottomed pools.

3633. West Fork of White River, just below dam, about four miles above Noblesville, August 20.

3634. Ripples in West Fork of White River, about three miles above Noblesville, August 20.

3635. Mud Creek about a mile above its confluence with Tippecanoe River, August 27.

3636. Pigeon River about two miles above Scott, September 4.

3637. Turkey Creek along state road 20, near Bushy Prairie, September 4.

List of Species

3.[2] *Calopteryx maculatum* Beauvois. **Boone**[3] (3632), **Jasper** (3529, 3533), **Madison** (3630), **Orange** (3534, 3535), **Pulaski** (3536), **Union** (3625).

4. *Hetaerina americana* Fabricius. **Fulton** (3635), **Hamilton** (3634), **Jasper** (3529, 3533), **Newton** (3517), **Orange** (3534), **Union** (3626), **White** (3622A).

5. *Hetaerina titia* Drury. **Lagrange** (3636—10 ♂). This species was associated at this locality with *H. americana* which was much more abundant. The males of *H. titia* (no females were seen) were quite wary, alighting always on the tops of weeds or bushes or the tips of overhanging branches of trees along the river, and taking flight at the first quick move in their direction. In contrast to this the males (and females) of *H. americana* flitted about in the lower vegetation along the water margins, and dozens of them could have been taken with little effort.

15. *Argia apicalis* Say. **Boone** (3632), **Carroll** (3621), **Hamilton** (3633, 3634), **Union** (3626).

16. *Argia moesta* Hagen. **Hamilton** (3633, 3634), **Orange** (3535), **Vigo** (3510).

17. *Argia sedula* Hagen. **Boone** (3632), **Fulton** (3623, 3635), **Union** (3626).

18. *Argia tibialis* Rambur. **Shelby** (3627), **White** (3622A).

20. *Argia violacea* Hagen. **Clark** (2610, 2611), **Clinton** (3523), **Jasper** (3529, 3531, 3533), **Madison** (3630, 3631), **Newton** (3517), **Orange** (3534), **Pulaski** (3527), **Shelby** (3627), **Union** (3625), **White** (3622A).

21. *Enallagma antennatum* Say. **Carroll** (3621), **Clay** (356), **Hamilton** (3633), **Jasper** (3529, 3533), **Madison** (3630), **Newton** (3516), **Pulaski** (3527), **Tippecanoe** (3522, 3524).

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[2]The numbers of Williamson's list of 1917 (Univ. of Mich., Mus. of Zool. Misc. Publ. 2) are used in the papers of this series.

[3]Names in bold face type refer to counties.

22. *Enallagma aspersum* Hagen. **Clark** (361, 366, 367, 3610, 3615). A total of 14 males were taken.

22a. *Enallagma basidens* Calvert. **Madison** (3631A).

24. *Enallagma carunculatum* Morse. **Carroll** (3621).

25. *Enallagma civile* Hagen. **Carroll** (3621), **Clark** (361, 362, 364, 366, 3610, 3615), **Clay** (356), **Greene** (3512), **Hamilton** (3633), **Newton** (357), **Tippecanoe** (359), **Vigo** (3510). Everywhere abundant.

29. *Enallagma exsulans* Hagen. **Carroll** (3621), **Clark** (362), **Hamilton** (3633), **Jasper** (3529, 3531, 3533), **Newton** (3517), **Union** (3626).

34. *Enallagma signatum* Hagen. **Carroll** (3621), **Fulton** (3623).

35. *Enallagma traviatum* Selys. **Clark** (363, 365). Two males and three females of this rather rare species were captured.

37. *Nehalennia irene* Hagen. **Carroll** (3621), **Fulton** (3623).

*37a. **Amphiagrion abbreviatum* Selys. **Jasper** (3529—1♂), **Tippecanoe** (3522—3♂2♀); also five males and two females from the Purdue Student Collection, all labelled "Lafayette," and dated as follows: May 4, 1930 (R. R. Heaton), May 5, 1933 (Schopmeyer), May 9, 1930, May 15, 1931, May 20, 1936, May 22, 1934, and May 27, 1933 (J. E. Leeds). Some of these have been recorded previously as *A. saucium*. The Indiana specimens of *A. abbreviatum* belong to a new subspecies soon to be described by Mrs. L. K. Gloyd, who has recently studied all of the material of this genus in the author's collection.

38. *Amphiagrion saucium* Burmeister. **Wabash** (3530).

41. *Ischnura posita* Hagen. **Fulton** (3623), **Parke** (355, 3516), **Union** (3626), **Wabash** (358).

43. *Ischnura verticalis* Say. **Boone** (3632), **Carroll** (3621), **Hamilton** (3633), **Jasper** (3528, 3529, 3531, 3532, 3533), **Madison** (3630, 3631), **Orange** (3534), **Pulaski** (3527), **Shelby** (3627, 3629), **Union** (3625, 3626), **Wabash** (358).

44. *Anomalagrion hastatum* Say. **Clark** (3610), **Fulton** (3623), **Greene** (3511), **Kosciusko** (Warsaw, Aug. 3, 1932, G. E. Gould).

48. *Cordulegaster obliquus* Say. **Clark** (3611, 3613). Nine males of this rare species were captured in the same locality where it has been captured in other years (Proc. Ind. Acad. Sci., 41:452; 44:234); a female was captured along the shore of Schlamm Lake, which is about two miles distant from the point where the males were captured, on the same date.

49. *Progomphus obscurus* Rambur. **Jasper** (3531—1♂, 3533—1♂1♀), **Warren** (3526—1♂).

52. *Erpetogomphus designatus* Hagen. **Hamilton** (3634). This species was rather numerous at ripples in the river, flying just above the surface of the water, and alighting on rocks. However, it was exceedingly difficult to capture, and only one male was taken.

52a. *Gomphus amnicola* Walsh. **Tippecanoe** (3622). A series of two males and three females were secured. These specimens fit perfectly into *G. amnicola*, as this species is characterized in Williamson's key to the species of the *intricatus*-group (Uni. of Mich., Mus. of Zool. Occ. Papers 247:3. 1932) and agrees in color with specimens from Knox

County, Indiana. However, there are slight differences in the form of the male genitalia and appendages and of the female vulvar lamina.

55. *Gomphus exilis* Selys. **Dubois** (3616—30♂4♀), **Vigo** (3513—1♀). At the Huntingburg lakes this species was very abundant along certain parts of the shore but was not seen at other parts.

58. *Gomphus graslinellus* Walsh. **Carroll** (3621—3♂6♀), **Grant** (July, 1935, 1♂, P.U.), **Warren** (3526—1♂).

59. *Gomphus lividus* Selys. **Orange** (3535—2♂1♀), **Warren** (3526—2♂).

60. *Gomphus quadricolor* Walsh. **Tippecanoe** (3521—1♂2♀).

62a. *Gomphus subapicalis* Williamson. **Greene** (3512—1♂). Special trips were taken to the localities (3510, 3513, 3515) where this species has been taken previously, but it was not found.

66. *Gomphus villosipes* Selys. **Jasper** (3529—1♀).

68. *Dromogomphus spinosus* Selys. **Tippecanoe** (3622—1♂).

70. *Boyeria vinosa* Say. **Union** (3626—1♂).

71. *Basiaeschna janata* Say. **Marion** (May 20, 1934, 1♂, P.U.), **Owen** (May 10, 1936, 1♂, P.U.).

72. *Anax junius* Drury. **Carroll** (3621), **Jasper** (3533). On October 2, 1935 H. E. Brown and the author collected about 200 specimens (approximately equally divided between males and females) of this species in the edge of a woodlot just west of West Lafayette. During the morning and early afternoon the temperature had been rather high, and the air was more or less calm. In mid-afternoon the temperature dropped rapidly as a brisk southwest wind began to blow. Our attention was attracted to these insects clinging to the trunks of small trees at the edge of the woods on the north and east sides of a large open field when we entered the woods about 3:30. At this time the insects could be picked from the trees with the hands if the collector were careful, but if disturbed they would fly to another tree. However, within thirty or forty minutes, as the temperature continued to drop, they became unable to use the wing muscles and would fall to the ground if shaken or knocked from the trees. Some were found as much as ten rods or more in from the edge of the woods but they were most abundant on trees about 20 to 50 feet from the edge. These insects had probably been "hawking" over the open field during the warm, calm mid-day and had been driven to shelter suddenly, causing them to be much more concentrated than they would have been if they had taken to cover normally with the approach of dusk.

*72a. **Anax longipes* Hagen. **Clark** (361). Soon after reaching the lake a male of *A. longipes* was seen. It flew parallel with the shore line—about 20 feet above the water and twice that distance from the shore—for a considerable distance, then across the lake and out of sight. Subsequent search for this or another individual of the species during the remainder of a five-day visit at the locality was unrewarded. It has been shown that sight identifications of birds in flight, which have been rather widely quoted as records, are likely to be inaccurate and such records of insects are usually very unreliable. However, the colora-

tion of *A. longipes* in life—bright green thorax and brilliant red abdomen —gives it a truly striking and majestic appearance, entirely different from that of any other North American dragonfly. As I have seen the species in flight previously in New Jersey where I collected it, I do not hesitate to record it for the state upon this sight record.

This species is not common even along the coast in its usual range from Massachusetts to Brazil, and the occurrence of individuals inland is very unusual. However, it probably has a more extensive range than the records indicate, as it is very difficult to capture. A male was taken at Lake Erie, near Sandusky, Ohio, in July, 1913, and the species has been observed in two other Ohio localities: over the Ohio River at Cincinnati by Charles Dury in June, 1898, and along a small stream in an open field near Wooster by the author in June, 1930. It was observed at the south end of Pelee Island, Ontario, by F. M. Gaige in June, 1918.

81. *Epiaeschna heros* Fabricius. **Clark** (a female clinging to a leaf overhanging a path at Purdue Forestry Camp, June 11, 1936, H. M. Brown), **Gibson** (3519—a male found, fluttering, on the ground beneath an overhanging bank and brush; apparently disabled or weakened from some cause).

83. *Macromia illinoiensis* Walsh. **Fayette** (Connersville, August, 1 ♂, P.U.), **Tippecanoe** (3622—1 ♂; also a male found on a sidewalk in Lafayette, during the summer of 1935, by A. W. Trippel).

87. *Epicordulia princeps* Hagen. **Carroll** (3621), **Dubois** (3616), **Orange** (3534), **Vigo** (3513, 3515).

89. *Tetragoneuria cynosura* Say. **Clark** (361—1 ♂, 363—2 ♂, 364—2 ♂), **Tippecanoe** (Lafayette, May 18 and 25, 1935—2 ♂, P.U.).

99. *Libellula luctuosa* Burmeister. **Carroll** (3621), **Hamilton** (3633), **Jasper** (3528, 3532, 3533), **Parke** (3516), **Pulaski** (3527), **White** (3622A).

100. *Libellula pulchella* Drury. **Carroll** (3621), **Jasper** (3529, 3531, 3533), **Pulaski** (3527), **Shelby** (3627), **Union** (3625).

102. *Libellula semifasciata* Burmeister. **Clark** (367—2 ♂ 1♀, 3611—4♀).

104. *Plathemis lydia* Drury. **Carroll** (3621), **Clinton** (3523), **Greene** (3512), **Jasper** (3528, 3531, 3533), **Pulaski** (3527).

105. *Perithemis tenera* Say. **Boone** (3632), **Hamilton** (3633).

106a. *Erythrodiplax minuscula* Rambur. **Clark** (363—5 ♂, 367—2 ♂ 1♀, 368—5 ♂ 1♀, 369—5 ♂, 3610—1♀, 3612—1 ♂), **Gibson** (3619—1 ♂). At Francke Lake this species was found in a marshy area of Sagittaria sp., along the lake margin; at Schlamm Lake it was discovered at the extreme upper end, in marshy areas along the lake margin and over adjacent water four to 10 inches deep. In the latter locality females were seen ovipositing by striking the tip of the abdomen against the surface of the water. At the Oakland City lake the specimen was taken on a dry slope a few rods from the lake margin.

107. *Erythemis simplicicollis* Say. **Carroll** (3621), **Greene** (3511), **Jasper** (3533), **Madison** (3630), **Newton** (3517), **Parke** (3516).

108. *Sympetrum ambiguum* Rambur. **Carroll** (3621—1 ♂ 1♀), **Clark** 365—1 ♂), **Gibson** (3518—6 ♂ 2♀). The Clark County specimen taken

June 10 was very teneral, and those from Carroll County taken 12 days later were rather teneral.

115. *Pachydiplax longipennis* Burmeister. **Carroll** (3621), **Jasper** (3528), **Madison** (3630).

*119a. **Celithemis fasciata* Kirby. **Gibson** (3619—1♀). This specimen is teneral and the only specimen of *C. eponina* captured at this time, June 15, is also teneral; however, of 37 males and 3 females of *C. elisa* taken at the same time only four were teneral.

This record extends considerably the recorded range of the species, which has been known previously from the Gulf Coast to Oklahoma and South Carolina, and shows an overlapping of the range of *C. monomelaena*, which has been recorded from Missouri. This specimen is typically *C. fasciata* in all of the seven characters used by Williamson (O. Nat., 10:153-160. 1910) to separate *C. fasciata* and *C. monomelaena*. However, two males of *C. fasciata* from South Carolina in the author's collection are more or less intermediate in some of these characters, and, according to Mrs. Gloyd, this is also true of specimens from Georgia *(C. fasciata)* and Missouri *(C. monomelaena)* in the Williamson Collection. A critical study of these species is apparently needed, especially as much more material is now available than was known at the time Williamson's study was made.

121. *Pantala flavescens* Fabricius. **Rush** (3628).

123. *Tramea carolina* Linne. **Clark** (361, 3611, 3614).

124. *Tramea lacerata* Hagen. **Carroll** (3621), **Clark** (363, 368).

Inherited Behavior in Drosophila

J. P. Scott, Wabash College

Introduction

It is a scientific truism that simple phenomena yield to analysis more readily than complex ones, and since the day of Fabre it has been a common impression that the behavior of insects, while sometimes forming an intricate pattern, is little affected by variations of the environment. Therefore, the observation of Dr. H. H. Strandskov that the stock of brown-eyed *Drosophila melanogaster* at the University of Chicago reacted more vigorously to light than did the wild appeared to offer fruitful ground for genetic experiment.

Materials and Methods

Three methods of measuring the response of an animal to a given stimulus suggest themselves: (1) the threshold value of the stimulus required to produce a reaction, (2) the strength of an opposing stimulus sufficient to overcome the effects of the stimulus studied, and (3) the speed of reaction to the given stimulus. The first method was abandoned because of the difficulty of exactly controlling the secondary stimulus (vibration) involved in the reaction of Drosophila to light. The second method would make the situation even more complicated, and the third has a disadvantage in that it is practically impossible, in a small, active animal like the fruit fly, to measure separately reaction time (time between the stimulus and reaction) and the speed of the reaction (time required to move a certain distance). However, the last method, including both reaction time and speed of reaction in a single measurement, was worked out to a point where consistent results were obtained and was adopted.

The apparatus designed (Fig. 1) was essentially a closed glass tube cut into three lengths of 6.1 cm., 18.3 cm., and 6.1 cm. The ends were made of two pieces of the same microscope slide, and the cut edges ground smooth. The different sections of the tube could be cut off from each other by an opaque barrier composed of two cover-slips cemented

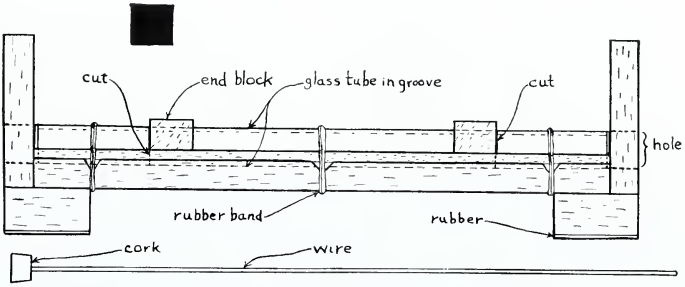

Fig. 1. Barrier, wooden rack carrying glass tube, and plunger. x ¼. The end blocks allow the short sections of the tube to be rolled out of line without loss of flies. The entire wood surface is painted black. The rack is one-third as wide as it is long.

to thin black paper. The tube was fastened horizontally upon a rack, and, since it had only 1.6 cm. internal diameter, little room was present in which the flies could react to gravity. A beam of light from an enclosed 40-watt Mazda electric bulb was shone directly down the tube, the illumination at the joints being approximately 6 and 16 candle power. Examination showed that the light was reflected evenly from the inner surface of the tube with little interference from the joints. All tests were made in a dark room, so that very little light entered the sides of the tube.

McEwen (1917) found that the reactions of females were interfered with by the number of eggs carried, and that the maximum phototropic response was developed at 3-5 days. Therefore, males only were used, raised at a temperature of 24-25°C. on cornmeal-agar-molasses medium and removed daily at 4 p. m. from a fresh stock bottle. These were fed on dilute medium which had been allowed to go to vinegar and which keeps indefinitely. On the fourth day at 4 p. m. the flies were shaken out into the testing tube and 19 out of the 25 or 30 present were selected at random and pushed with a plunger into one of the small sections of the tube. This was tightly stoppered with cotton and placed in the dark for three hours.

During the test an attempt was made to avoid all jarring involved in handling the rack and lifting the opaque barrier which replaced the cotton plug. The tube containing the flies was placed on the lighted end of the rack and the whole left in that position for two minutes. The rack was then reversed and entirely covered for three minutes. The cover was removed, the barrier lifted, and the time at which the tenth fly reached the second cut in the tube recorded with a stop watch. All flies were then pushed into the lighted end and the procedure repeated for a total of 10 trials. An air temperature of 24-25°C. was maintained throughout the test.

All of the stocks used had been inbred over a period of years by reason of the small number used to start each new stock bottle.

The wild stock, which is normal, shows the same pigment in the eyes throughout adult life. These flies emerge from the pupa case with grey bodies, the black pigment being at first concentrated in a spot in the abdomen. The body becomes progressively darker with age, finally becoming yellow with black bands.

On the other hand, brown flies emerge from the pupa case with light brown eyes, which rapidly darken to a cherry red. The body pigment at emergence is darker than that of the wild, and the black markings are always more intense. Brown flies are smaller in size and more constantly active under stock-bottle conditions and, in this particular stock, at least, appear to lay their eggs somewhat later after mating, with the result that there are more sterile matings than in the wild stock.

White is epistatic over brown, and, with an eye to future genetic experiments, the white stock was also tested. This type entirely lacks red pigment in the eyes. As in the wild, yellow body pigment is absent at emergence but appears gradually with age in both eyes and body. It probably does not reach the full depth of color seen in the wild stock. Development is slower than with the wild, but the stock lays its eggs

promptly after mating so that sterile matings are practically unknown. Under favorable conditions size may exceed that of the wild, but under unfavorable conditions it may be more greatly reduced. White flies are decidedly less active than the wild. Both brown and white soon disappear in competition with wild in stock bottles.

Analysis of the Response

When highly stimulated by vibration the flies respond to the light by almost immediately starting toward it in a body, crawling in straight lines. When less highly stimulated the flies wait some time after exposure to the light before crawling toward it and may crawl only a short distance. The effects of a vibratory stimulus last for several minutes.

Tests of the white, brown, and wild stocks were made, with the results shown in Table I. The brown stock differs from both the wild and white in mean and standard deviation. Wild and white differ in the mean, but not significantly in standard deviation. The brown stock is therefore faster and less variable than the other two.

TABLE I. TIME OF PHOTOTROPIC RESPONSE OF FLIES SUBJECTED TO MINIMUM VIBRATION

Stock	No. Trials	Mean	Standard Deviation
Wild	30	17.89±0.59	3.25±0.42
Brown	39	14.49±0.23	1.46±0.17
White	30	21.23±0.76	4.18±0.54

As Carpenter (1905) originally showed, the phototropic response of Drosophila takes place only when the flies are mechanically agitated. Under the conditions of the test, the flies are agitated at the begining by the placing of the tube upon the rack. While in the lighted end the flies constantly collide with one another, and they are jarred slightly by the reversal of the rack and friction of the barrier with the cut edges of the tube. All other sources of vibration were eliminated so far as possible. From the variable behavior of the wild and white stocks it appeared that this amount of vibration was somewhere near the minimal amount necessary to obtain a response in these groups. The brown stock, on the other hand, appeared to be highly stimulated at all times.

It was then supposed that the essential difference between the brown stock and the others was a difference in susceptibility to vibration. A small amount of additional vibration was produced by vibrating a ruler attached to the table on which the rack was resting, just before the barrier was lifted. The results are shown in Table II. With the exception of one lot of brown flies which was lost, the same flies as in Table I were used.

The mean time of the brown stock is significantly reduced by this amount of vibration, but the others are little affected if at all. It can

therefore be concluded that the brown stock is more susceptible to vibration than the wild or white, since the latter two stocks may be made to respond as rapidly as the brown by sufficient shaking. It is obvious that the difference is hereditary, but it has not been demonstrated that the difference is actually produced by the *bw* gene.

TABLE II. TIME OF PHOTOTROPIC RESPONSE OF FLIES SUBJECTED TO REGULAR JARRING

Stock	No. Trials	Mean	Standard Deviation
Wild	30	18.23±0.58	3.18±0.41
Brown	30	12.59±0.24	1.34±0.17
White	30	20.09±0.64	3.53±0.46

On the other hand, there is no indication of difference in susceptibility to vibration between the white and wild. The foundation for the difference appears to be simply the more sluggish movements of the white flies. Cole (1922) was unable to get any consistent response of white flies to changes in intensity of light, but this factor is not involved in the present experiment.

The susceptibility of Drosophila to small amounts of vibration is amazing. Passing trucks on the street and a small power saw in the lower floor of the building in which the first experiments were made were sufficient to produce unrepeatable results. The flies were found to be responsive to small bits of lint left in the tube, which had to be kept perfectly clean, and to be markedly disturbed by variations in temperature of as little as half a degree. Below 22° C. the brown stock would sometimes react more slowly than the wild. Freshly fermented food fed the adults produced sluggish behavior, and the conditions under which the larvae were reared also produced variation, probably through alteration in size. In order to get repeatable results environmental conditions must be rigorously controlled.

McEwen (1917), although keeping only a very rough control over environmental and accessory hereditary factors, concluded that age, sex, the size of the wings, and specific genes affect the response to light. Cole (1922) reported that the photic response (in the vertical direction) was made faster by an increase in illumination. Summarizing the available evidence, it may be said that the "phototropic" response of Drosophila is affected by several different hereditary (internal) factors and by the following important environmental factors: light, vibration, temperature, and food.

Discussion

The amount of variation in the data given is accounted for by accidental variation of the environmental factors mentioned above and by errors of measurement introduced by the operator. Payne (1911)

used a technique which approaches fairly closely the one described here. Adjusted for different length of tube, his figures show an average time of about 13.5 seconds for wild flies. The faster time can probably be accounted for by the increased jarring involved in his technique. In any case, the test described in this paper gives the result expected under the mechanistic theory of behavior, a reaction predictable in terms of probability under a controlled set of conditions.

However, the idea that environmental factors play only a small part in determining the behavior of insects is obviously incorrect in this case. Under natural conditions, with all the controlling factors varying and largely independent of each other, an enormous variety of reactions to light can be observed.

This being so, the use of the term "tropism" becomes questionable. Loeb's (1918) idea that the energy derived from a stimulus helps to move an animal toward or away from that stimulus (producing a "forced movement" or tropism) was discredited on the grounds of oversimplicity by Jennings (1923), who replaced it with the theory that with regard to injurious and beneficial stimuli an animal tends to come to rest in the most favorable position, though not necessarily responding directly to the stimuli. That is, tropisms are adaptive behavior. The adaptive value of the "phototropic" reaction of Drosophila has been pointed out by Mast (1911) to be a means of escaping engulfment in rotten fruit. Jennings further concludes that all behavior is more or less adaptive, and that the term "tropism" is therefore meaningless.

Still, superficial observation will discover many cases of behavior in the lower organisms in which an animal apparently responds positively or negatively to a single stimulus. Given the proper conditions, a fruit fly will hasten directly toward a source of light, paying no attention to other stimuli. On analysis, this behavior is found in a situation where one stimulus, that of vibration, is so intense as to overcome the effects of all other stimuli.

This sort of behavior is not confined to the lowly organized animals. A man might be said to exhibit negative thermotropism in the face of a forest fire, or to be negatively phototropic at a temperature of 100°F. Even if tropism were redefined to mean unusual susceptibility to a particular stimulus toward which a positive or negative reaction was given, the term would become entirely relative and so retain practically no descriptive power. The analysis of behavior in Drosophila, at any rate, leads inevitably to Jennings' conclusion that "tropism" should be abandoned as a specific scientific term.

Summary and Conclusions

1. An attempt was made to measure the response to light of inbred wild, brown, and white stocks of Drosophila.

2. The technique used was the measurement of the average time required to traverse a distance of 18.3 cm. toward an electric light under standard conditions.

3. The mean times for the three stocks differ significantly, white being the slowest and brown the fastest. The brown stock gave less variable results than the other two.

4. The difference between brown and wild was found to be produced by differential susceptibility to vibration, whereas the difference between white and wild appears to be caused by the slow walking speed of the former.

5. These hereditary differences in behavior do not appear to be caused directly by differences in eye pigmentation.

6. The following major environmental factors also affect the response to light: vibration, light, temperature, and food.

7. The assumption that insect behavior patterns are controlled almost exclusively by heredity does not apply to Drosophila.

8. The data suggest that the meaning of the word "tropism" is entirely relative and that the term should therefore be abandoned.

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The Incidence of Animal Parasites of the Brown Rat *(Rattus Norvegicus)* in Tippecanoe County, Indiana

Raymond M. Cable and William Hugh Headlee, Purdue University

Introduction

The common rat, in addition to being a destructive pest, is known to serve as host for a number of animal parasites which also occur in man. Perhaps all of the major groups of endoparasites may be represented by species common to both man and rats. Among the cestodes, *Hymenolepis nana* and *H. diminuta* are common parasites of both man and rodents, and the cysticercus of the pork tapeworm of man, *Taenia solium*, is occasionally reported from rats. The hydatid cyst of *Echinococcus granulosus* and the cysticercus of *Taenia hydatigena* are occasional parasites of both human beings and rodents. In addition to these, the larval stages of certain tapeworms of domestic animals parasitize the rat. *Cysticercus fasciolaris*, the larval stage of *Taenia crassicollis*, the cat tapeworm, is a cosmopolitan parasite of the rat, and the larva of *Taenia pisiformis*, the tapeworm of the dog and rabbit, is also reported occasionally from rodents.

Certain species of nematodes also find both man and rats suitable hosts. This is especially true of *Trichinella spiralis*, *Syphacia obvelata* and *Hepaticola hepatica*. The acanthocephalan, *Moniliformis moniliformis*, has also been reported from man and rats.

Most of the protozoa of rats are described as distinct species, but in certain cases perhaps the only demonstrable difference between species in man and those occurring in rats is that different hosts are involved. For example, *Endolimax ratti* is morphologically indistinguishable from *E. nana* of man. Chiang (1925) claims that *E. ratti* is a valid species since he was unable to infect rats with *E. nana*. However, Kessel (1923) had previously claimed to have infected rats with the human species. Another protozoan, *Endamoeba muris*, is very similar to the human species, *E. coli*. The importance of the rat as a reservoir host of the plague bacillus is well known and calls for no emphasis in the present discussion.

Since the rat serves as host for a number of parasites which may become established in man and domestic animals under suitable conditions, a study of the incidence of animal parasites in rats of the Lafayette region appeared desirable.

Materials and Methods

Many rats were killed in Tippecanoe County last February when the flood forced hundreds of them from their burrows along the Wabash River. The animals examined in this study had been dead for over a day when obtained, and many of them seemed to have been frozen. For this reason, the material did not afford a favorable examination for intestinal protozoa. In certain cases, however, positive diagnoses of protozoa were possible.

The blood, diaphragm, intestine, and feces of the rats were examined.

The blood examination was made by diluting a small amount of blood with normal saline and examining under the microscope. In searching for *Trichinella*, a portion of the diaphragm was compressed between glass slides and examined. Intestinal parasites were detected by slitting the intestine along its entire length and scraping out the contents into a finger bowl of normal saline and examining with a low power binocular microscope. In making the coprological examinations, a bit of fecal material was removed from the large intestine and examined microscopically for protozoa and for ova and larvae of helminths.

Observations and Discussion

The parasites noted and the incidence of infection are listed in Table I. The incidence of *Tritrichomonas* infections is lower than that usually observed, due to the unfavorable condition of the material examined. In all cases of infection with *Trypanosoma lewisi*, the parasites were very active. This resistance to unfavorable conditions is surprising, and the high incidence of this parasite is unexpected in view of known facts concerning its life-cycle. The high incidence may be due either to mass infection or to latent infections that may have been released from inhibiting factors by the lowered resistance or death of the host. In the latter case, there must have been a rapid post-mortem multiplication of the trypanosomes. When the condition of the host and activity of the parasites are considered, this seems entirely possible. Viability of the trypanosomes was determined by inoculating uninfected laboratory rats. The result was heavy infections, which were observed during a period of several weeks.

TABLE I.

INCIDENCE OF ANIMAL PARASITES OF THE BROWN RAT (RATTUS NORVEGICUS) IN TIPPECANOE COUNTY, INDIANA

Parasite	No. Inf.	% Inf.	Parasite	No. Inf.	% Inf.
Tritrichomonas muris...	6	15.0	Hymenolepis diminuta.	3	7.5
Trypanosoma lewisi.....	19	47.5	Hymenolepis nana.....	3	7.5
Endolimax ratti.....	1	2.5	Trichocephalus muris..	1	2.5
Eimeria nieschulzi.....	2	5.0	Trichinella spiralis.....	1	2.5
Cysticercus fasciolaris...	35	87.5	Nippostrongylus muris.	30	75.0
			No. of rats examined...	.....	40

The high incidence of infection of *Cysticercus fasciolaris* and the fact that usually a single cyst was found in the liver of each rat is in accord with the experimental results of Miller (1931). Since the incidence of this parasite is high, it is likely that rats are frequently exposed to infection, and, if the presence of a single cyst did not stimulate an immune reaction on the part of the host, it seems that cases of

multiple infection would be more frequent than the present observations indicate. The maximum number of cysts recovered from a single rat was five, while by experimental feeding of tapeworm eggs, it is possible to recover over 100 viable cysts in a single case (Miller, 1931).

Nippostrongylus muris is a common parasite of rats and has been used extensively in investigations concerning immunity and host-parasite relationship. This nematode was originally described as *Heligmosomum muris* by Yokogawa (1920), who found the species of common occurrence in Norwegian rats taken in Baltimore, Maryland. Lane (1923) erected the genus *Nippostrongylus*, thereby separating it from other genera of the subfamily Heligmosominae, chiefly on the basis of the asymmetrical bursa of the male.

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Studies on Poisonous Snakes of Indiana

W. P. Allyn, Indiana State Teachers College

The straggling remains of three species of poisonous snakes still inhabit certain sections of Indiana: the Timber Rattler *(Crotalus horridus)*, Prairie Rattler or Massasauga *(Sistrurus catenatus)*, and Copperhead *(Agkistrodon mokasen)*.

The Timber Rattler appears to be confined to the high, dry, rocky, and wooded sections of the state. Some twenty-five specimens have been collected during the past five years, all of which came from Brown County and vicinity. Two phases have been found, the dark and light phases, and in both cases the female is the lighter of the two. The Timber Rattler is not vicious in captivity, as a rule, but appears melancholy and does not take food willingly. This species may be readily recognized by the roughly chevron-shaped black blotches on the back superimposed upon a sooty-yellow body. Posteriorly, the tail becomes black.

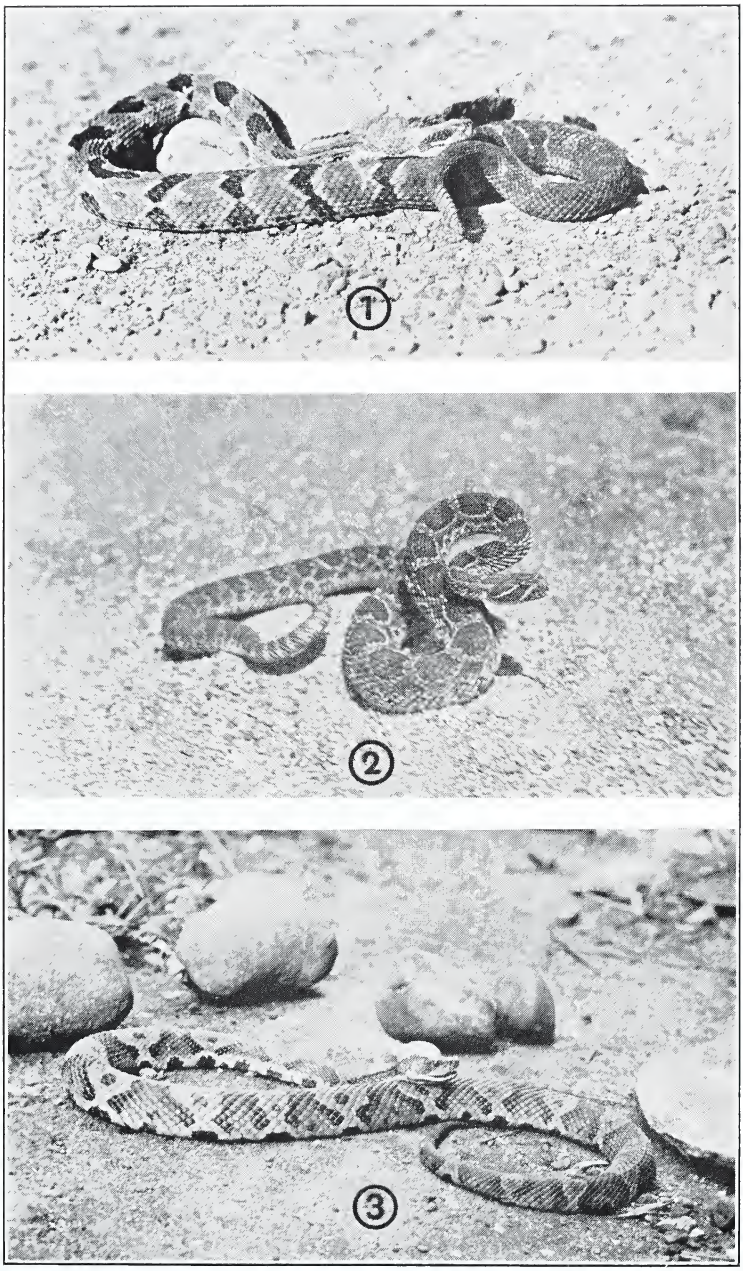
The Prairie Rattler has survived, it would seem, in the low, swampy regions of Northern Indiana—regions in the main not well adapted to agricultural pursuits. Only two specimens have been collected by the writer, both of which came from the vicinity of Cedar Lake. Unofficial reports, however, have been received from other sections.

The Prairie Rattler is by far the more vicious of the two Indiana rattlers. This nervous little warrior shows no signs of retreat when approached. In fact, on one occasion while adjusting the lens of a motion picture camera, the writer glanced up in time to find this fellow edging up closer and expressing all indications of fight. Its body color is olive-gray with a dorsal series of rounded dark blotches. A characteristic dark brown band bordered with white extends diagonally from the corner of the mouth down the side of the head below the eye. The belly is dark and mottled.

The Copperhead remains generally but sparsely distributed in the high, dry, and rocky regions of Indiana from the central portion south. Specimens have been collected from Brown County and vicinity, Harrison, Perry, Posey, and Putnam counties.

The Copperhead can be readily recognized by the coppery-colored head and a series of uniform hour glass-shaped blotches of chestnut-brown on the back. This reptile is an unpretentious, graceful, and beautiful little creature, but treacherous. It never spars with its adversary, as do the rattle-snakes, but throws itself into a figure S coil and strikes simultaneously. On several occasions, alley rats were introduced into an open pen containing both rattle-snakes and copperheads. Invariably a copperhead killed the rat while the rattlers were sparring for alignment on the victim.

Quantities of Venom Exuded.—It is recognized that no great importance is attached to the exact quantities of venom exuded by poisonous reptiles. Moreover, such factors as the age, size, and species of reptile, together with the degree to which the animal may have been depleted of venom before the test, offer considerable variation. The



Figs. 1-3. Venomous snakes of Indiana. Fig. 1. Timber Rattler *(Crotalus horridus)*. Fig. 2. Prairie Rattler *(Sistrurus catenatus)*. Fig. 3. Copperhead *(Agkistrodon mokasen)*.

viscous nature of the venom, the small quantities exuded at a single bite, and the hazards accompanying the extraction also present technical problems.

Simple apparatus was devised for measuring the venom. A small glass funnel was sealed on the end of a 1 cc. pipette. The opposite end of the pipette was stopped with a paraffin plug and the funnel covered with two layers of gauze tied about its neck with a rubber band. The funnel was manipulated with one hand and the reptile with the other. The snake, held close behind the head, was brought up to the funnel and permitted to sink its fangs through the gauze and deposit its venom into the funnel. The venom was kept suspended up in the pipette by an air cushion between it and the paraffin plug. After disposing of the reptile, the paraffin plug was punctured and the venom let down into the pipette for measuring.

Healthy snakes were used and they were permitted to remain some seven to ten days undisturbed prior to the test. The reptiles were not permitted to chew on the gauze but to insert the fangs one time only at each trial test.

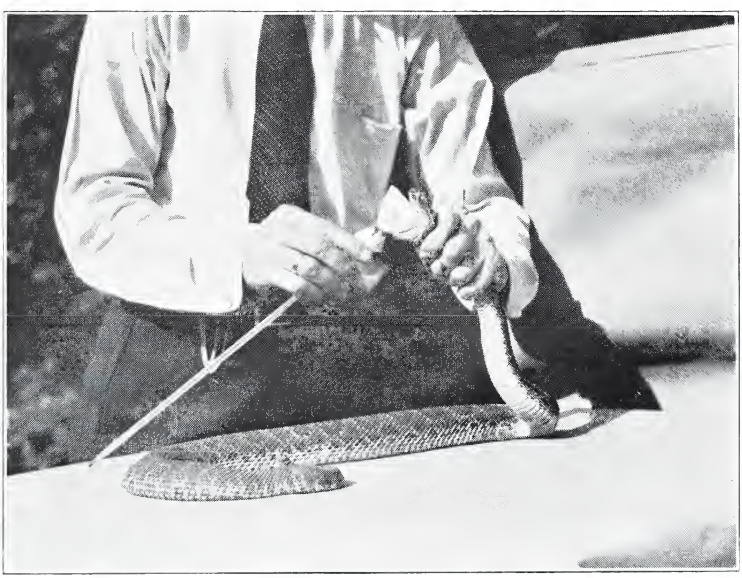


Fig. 4. Method of extracting and measuring venom *(Prairie Rattler)*.

The Timber Rattler (4 ft. 9 in. long) gave out approximately 0.5 cc. of venom at the first and second bites; at the third, between 0.2 and 0.3 cc.; and at the fourth bite the quantity was materially reduced to about 0.1 cc.

The Copperhead (3 ft. 3 in. long) gave a dosage of approximately one-half that of the Timber Rattler but decreased at successive bites in much the same ratio.

Effects on Rats.—The lethal effect of the first and successive dosages of the Timber Rattler was then tried on alley rats as experimental animals. The rats were trapped in a wire box to prevent injury. A type of harness was made to shackle the rat during the tests. *Reptiles frequently strike but fail to make contact.* In order to assure actual contact, the snake was held close behind the head and induced to sink its fangs into the peritoneal cavity of full grown rats. The first rat traveled about ten feet, fell over on its side, palpitated, and died within ten minutes. The snake was released and permitted to regain its composure before each successive test. The second and third rats died within ten to fifteen minutes, whereas the fourth rat quaked a bit but recovered.

Moreover, it was noted that the Prairie Rattler was able to kill a full grown rat every day for five successive days, the end of the experiment. Hence it would appear dangerous to assume that a rattle-snake is devoid of venom after an engagement with an adversary and will remain so seven to ten days as is popularly believed. The supply of venom obviously is gradually depleted and restored in much the same way.

Effects of Venom by Self-inflicted Wounds.—Sentimental stories have found way into current periodicals about reptiles growing melancholy in captivity and taking their own lives. An effort was made to check the effect of self-inflicted wounds on the Indiana species, which probably are no rare exception to the rule.

In each case the reptile was caught and agitated, and then its head was thrust around into a biting position at the mid-section of its own body. The rattle-snakes and copperheads were all very reluctant about sinking their fangs into the flesh of their own bodies. It was possible, however, with repeated effort to induce the animal to sink its fangs deep into its own flesh and inject its venom. In no case did the venom prove fatal. Some swelling was observed within the immediate regions of the wounds. Also the Prairie Rattler showed signs of sluggishness, but all recovered within a few days.

Effects of Bites on Other Poisonous Species.—A triangular experiment was arranged in which each of the three venomous species was permitted to bite another—the Copperhead to bite the Prairie Rattler; the Prairie Rattler, the Timber Rattler; and finally the Timber Rattler, the Copperhead. After a seven-day interval the program was reversed; thus each reptile was induced to bite both of the other two and was bitten in return by them. In all cases the animals were controlled and the bites directed to the mid-section of the other animal's body.

In no case did the venom prove fatal. Slight swelling occurred in the region of the wounds and the snakes appeared somewhat sluggish for a few days but recovered readily. The Copperhead, the smallest of the group, seemed to exhibit less signs of toxemia than either of the other two.

Effects on Non-venomous Species.—The bite of a Timber Rattler proved fatal to a Pilot Blacksnake *(Elaphe obsoleta)*, 5 ft. 6 in. long, within thirty-six hours after the incident, and to a common Water Snake *(Natrix sipedon)*, 3 ft. long, within three hours. The wounds in both

cases were inflicted under controlled conditions about one foot behind the head in the heavy portion of the body. Both snakes went into a coma and haemorrhaged at the nose before death. A post-mortem indicated that the fangs had entered the lungs and that large haemorrhagic areas were present around the wounds, both in the body wall and lung tissue. Obviously the venom itself had played an important role aside from the mere punctures made by the fangs.

On another occasion a common Blacksnake *(Coluber constrictor)* was placed in the cage with a small Diamond-back Rattler, 3½ ft. long. The rattler viciously attacked the Blacksnake and there was no doubt that the fangs hit their mark repeatedly during the encounter. Surprisingly enough the Blacksnake did not die, nor did it show any appreciable ill effects from the engagement.

It is generally understood, on the other hand, that the King Snake *(Lampropeltis getulus)* is immune to the venom of poisonous species. A small King Snake was accidentally placed in a cage with a small Massasauga by one of the assistants in the laboratory. A stick was placed over the neck of the sturdy little rattler for safety while attempting to remove the King Snake. It happened that the King Snake maneuvered over near the struggling little Massasauga and was bitten just behind the head in the neck. Within one hour the King Snake was removed from the cage dead.

It is recognized that the incidents cited here are not sufficient to warrant any general conclusions; nevertheless, it would appear that the lethal effect of venoms, explained in terms of species-variation alone, is probably subject to considerable variation. The ages of the reptiles, the quantity of venom injected at the time of the bite and the region of the victim's body receiving it, the general physiological state of both the donor and recipient, as well as species-variation, may all be contributing factors.

Additional Observations on the Salamanders of Putnam County and Vicinity

A. E. Reynolds, DePauw University

A year ago, an initial report on the area under consideration was made by presenting an account of the caudate Amphibia that occur in Putnam County (Reynolds and Black, 1936). Continued studies have not only included this county but have also been extended to include a wider territory. In addition to a corroboration of the previous report in all essential details, sufficient new information has been obtained to warrant presentation here.

I. *Eurycea lucifuga*, the "Cave Salamander" of Rafinesque

In the previous account, the data presented on *Eurycea lucifuga* were scant because of lack of material. Continued search failed to yield additional specimens from Putnam County. On account of its known preference for the cave habitat, it was sought, and found, in the "Sunken Cave" in McCormick's Creek State Park, Owen County. With the more abundant material from this cave at hand, more adequate data are offered here.

1. Description.—The animal presents a delicate and gracefully proportioned appearance. The tail is compressed, while the body is

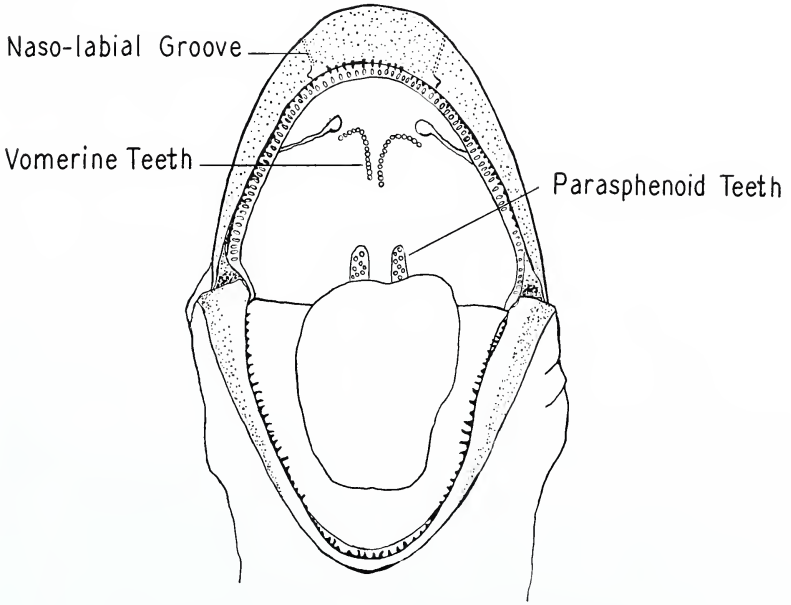


Fig. 1. Mouth cavity of *Eurycea lucifuga* (No. 145a) drawn from a ventral and slightly anterior view. (x 5). Distance from tip of snout to angle of jaws, 8.0 mm.; width of head at angle of jaws: internal, 7.8 mm., external, 10.4 mm.; distance from posterior limit of vomerine teeth to anterior limit of parasphenoid teeth, 1.7 mm.; distance of internal nares apart, 3.4 mm.

somewhat depressed, and the head decidedly so. The head is the widest part of the entire body, being in width about one-sixth the length of the head and body. The legs are fairly long and the toes somewhat short and blunt. When pressed against the sides of the body, the toes of the front and hind legs overlap slightly. The toes are 4, 3, 2, 5, 1 in order of length; the fingers, 3, 2, 4, 1. The ground color is reddish or orange dorsally and laterally, pinkish white ventrally. The ventral side is immaculate, but the dorsal and lateral regions bear irregular black spots. In some specimens, especially adults, these spots tend to form a line from the level of the front limb to that of the anus, but for the most part the spots are arranged indiscriminately. The head is quite flat as viewed from the side, the eyes protruding conspicuously. Viewed dorsally, the head is oval in shape. The naso-labial grooves are swollen, and in males these are extended ventrally into a cirrus free of the upper lip. The length of the eye is as great as the distance of its anterior border from the tip of the snout. The angle of the jaw occurs at a point ventral to the posterior angle of the eye. A short groove runs from the angle of the jaw dorsally to the groove of the lower eyelid, and a groove extends from the eye along the sides of the neck to the gular fold. The vomerine teeth, about 15 in each bilateral series, form an obtuse angle, presenting a hook-shaped appearance. They are separated from the bilateral patches of parasphenoid teeth. Relations are shown in Figure 1.

2. Measurements.—These may be readily seen in Table I, in which all lengths are expressed in millimeters. The first ten animals are from the "Sunken Cave"; the eleventh, from another locality, is listed for comparative purposes.

3. Habits and Ecology.—Sunken Cave descends vertically for perhaps 20 feet before extending horizontally, by way of a short, narrow

TABLE I. MEASUREMENTS OF EURYCEA LUCIFUGA

	Head	Body	Tail	Total	Costal Grooves	Body Weight	Remarks
1	14.5	49.3	73.6	137.4	13	3.5 gm.	Living specimen etherized
2	13.0	42.0	69.0	124.0	13	1.9 gm.	Living specimen etherized
3	12.0	40.0	72.9	124.9	14	1.4 gm.	Living specimen etherized
4	10.9	34.0	60.0	104.9	14	0.9 gm.	Living specimen etherized
5	9.8	31.0	54.9	95.7	14	0.8 gm.	Living specimen etherized
6	9.8	31.5	49.6	90.9	14	0.6 gm.	Living specimen etherized
7	15.0	48.6	75.3	138.9	13	3.5 gm.	Preserved, D.P.U. #145a
8	12.5	47.9	67.0	127.4	14	2.0 gm.	Preserved, D.P.U. #145b
9	13.8	43.7	78.0	135.5	14	3.0 gm.	Preserved, D.P.U. #145c
10	10.8	37.0	67.8	115.6	14	1.5 gm.	Preserved, D.P.U. #145d
11	13.0	42.3	92.0	147.3	14	_	Preserved, D.P.U. #119, formerly F.M.N.H. #19226.

passage, into a chamber of no great size, though of considerable height. The specimens of *Eurycea lucifuga* were found from the completely dark chamber out into a "twilight zone" of definitely diminished light. None were found in the upper regions of the vertical shaft where the light was approximately normal. In the dark room, they were found clinging to the perpendicular or slanting moist rock wall, and in the "twilight" area they were found in crevices of the horizontally stratified rock which forms the sides of the vertical shaft.

In the laboratory, specimens placed in aquaria in ordinary light and temperature showed a high mortality, but no casualties resulted among specimens kept in a cool room and in a darkened container. I have never kept specimens in aquaria containing water. They seem to thrive in dark containers containing dead leaves that are barely moist. They are quite sensitive to light and will not remain still if placed in well-lighted situations.

4. **Discussion.**—It is of interest to note that this species was, in the early Indiana records, confused with a species of similar appearance, *Eurycea longicauda*. One of the charter members of the Indiana Academy who is still active, Mr. Amos W. Butler, had an active part in the establishment of the true relationships of the two.

On the occasion of the meeting of the Academy at Waveland in May, 1887, trips were made to two regions in Montgomery County. "The Shades" and "Pine Hills," for the study of the natural history of these regions. In the account of the amphibians and reptiles of these regions, Mr. Butler (1887) lists *Spelerpes* (now *Eurycea*) *longicaudus* (Green) as being the more common at Pine Hills, further stating: "They are of a decided lemon color, thereby differing much from the form found in the southeastern part of the state, which approaches *S. ruber*." Later, speaking of this latter orange-colored salamander before the Academy at the meeting in 1888, Mr. Butler emphasized the desirability of obtaining a good series of specimens of this "Cave Salamander" as soon as possible in order that its relationship might be determined. He continues: "So far as I have learned, those of the western part of the state appear to be typical *longicaudus*. But one of this kind has been found in the southeastern part of the state. The specimens from that region have the form of *longicaudus*, but instead of the lemon-yellow coloring of that form, approach the reddish appearance of *S. ruber*, but lack the peculiar form of the latter" (Butler, 1892).

Following the meeting of the American Association for the Advancement of Science at Indianapolis in 1890, Prof. E. D. Cope visited Mr. Butler at Brookville and was given some of the reddish salamanders from that region. In the resulting description (Cope, 1890) the close resemblance to *S. longicaudus* is recognized, but the form is assigned to the genus Gyrinophilus as a new species, *Gyrinophilus maculicaudus*. A year later, Hay (1891a) published an account based on the examination of several specimens. In this he differs with Cope as to the premaxillaries, which he found anychlosed and not separated, as Cope had claimed, and on the basis of his findings Hay places the form in the genus Spelerpes as *Spelerpes maculicaudus*. Both of these views are given in

Mr. Butler's paper of 1892 under a description of *Gyrinophilus maculicaudus*.

Inasmuch as this discussion took place a year or more after the publication of his "Batrachia," Cope (1889) does not mention this species in this work. Hay (1891b) however, lists it as *Spelerpes maculicaudus*, the "Hoosier Salamander," and differentiates rather carefully between its characteristics and those of *S. longicaudus* by stressing the color difference and the differences in vomero-palatine teeth, as well as the difference in arrangement of spots. Dunn (1926) mentions it as *Eurycea lucifuga*, the "Cave Salamander" of Rafinesque.

II. Relative Numbers of *Plethodon*

Plethodon cinereus exists in two color phases, the gray-backed or unstriped phase, and the red-backed or striped phase. Writing long ago, Blatchley (1891) found that these phases were approximately equal in Vigo County, Indiana. In Michigan, Blanchard (1928, p. 158) found them in the same relative numbers. However, Grant (1936, p. 323), reporting on northern Indiana, gives 30% red backs to 70% gray backs as the approximate ratio in the Valparaiso area. Our results, to date, indicate that in central Indiana a markedly different situation exists. Far from being the most numerous, or even equal in numbers, the gray-backed phase is definitely the less numerous. Results to date from Putnam County indicate that the gray-backed phase will not exceed 10% of the total numbers of *P. cinereus*. Typical results from short collecting trips made to favorable regions in Parke and Montgomery counties are summarized in Table II.

TABLE II. RESULTS OF SHORT COLLECTING TRIPS

	Bell's Wood Montgomery County	Turkey Run Parke County
Plethodon cinereus, red-backed or striped	9	52
Plethodon cinereus gray-backed or unstriped	1	12
Plethodon glutinosus	4	11
Plethodon dorsalis	14	25

Table II also reveals a relationship between comparative numbers of *P. cinereus* and *P. dorsalis* which differs from that in Putnam County, where *cinereus* outnumber *dorsalis* by about 25 to 1. The table shows *dorsalis* to be the most numerous in the Bell's Wood region, a result in harmony with a report on Montgomery County (Grave, 1931, p. 339) which included this region. In the Turkey Run region in Parke County, *cinereus* outnumbers *dorsalis*, but not in such a high ratio as in Putnam County. In connection with this high ratio of *cinereus* to *dorsalis* in Putnam County, it should be pointed out that a single exception to the

general rule was found in the "Oakalla" locality not far from Greencastle. In this locality, which was discovered by Mr. E. G. Black, *P. dorsalis* was abundant to the practical exclusion of all other salamanders.

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Insects of Indiana for 1936[1]

J. J. Davis, Purdue University

Since our last report we have experienced extremes of weather during the winter period and during the following summer, which have played an important part in the abundance or scarcity of certain insects and which have given additional data on the effect of such abnormal conditions on insect life. Not only did Indiana experience a summer of high temperatures and low rainfall, but these extremes followed a winter of abnormally low temperature. The severe winter was responsible for the general belief that high insect mortality would result and that insects would be minor factors during the following season. However, in general, this was not the case, for Indiana experienced at least as many and as severe insect problems as during the average years.

The severe winter, with the temperature going as low as -18°F. at Indianapolis and -27°F. in some parts of the state, did result in a high mortality of some species that live exposed during the winter months, as does the San Jose scale, and also among those, such as the Mexican bean beetle, harlequin bug, and bagworm, which are of southern origin but which had extended their northern range as a result of recent mild winters. However, even with the majority of insects which are affected by the winter cold, the winter mortality is less important than the effect of spring and early summer conditions. In other words, insects possess such a remarkable reproductive capacity, that with favorable conditions early in the season, a comparatively few individuals passing the winter successfully may be able to increase to destructive numbers by midsummer or later. The winter weather may, on the other hand, be responsible for the abundance or scarcity of insects in other ways. Thus, the severe winter of 1935-36 weakened peach trees, which enabled the shot hole borer to increase greatly, since this insect can gain a foothold in stone-fruit trees only after they have been weakened from one cause or another.

The extreme heat and drought of the past summer perhaps played a more significant rôle than did the winter cold, but here again the extremes were favorable to some insects, such as codling moth and chinch bug, although definitely harmful to others, such as European corn borer and Mexican bean beetle. On the other hand, we find that these extreme conditions were also indirectly responsible for insect damage. For example, in many sections of the state, where grasshoppers were abundant in "idle" weedy land, the drought dried up their normal food, and they were forced to migrate to cultivated crops, especially corn, to complete their growth.

[1]Contribution from the Department of Entomology of the Purdue University Agricultural Experiment Station, being a continuation of a series of annual summaries begun in 1925, dealing with the major insect problems of Indiana and the relation of weather to abundance or scarcity of different species. The writer expresses his appreciation to the following who have provided records: C. M. Packard, Philip Luginbill, E. V. Walter, W. B. Noble, Curtis Benton, H. R. Painter, L. F. Steiner, A. J. Ackerman, John Amos, H. K. Rippey, G. E. Marshall, G. A. Ficht, G. E. Gould, D. W. LaHue, G. E. Lehker, H. O. Deay and B. E. Montgomery.

The accompanying table (Table I) gives a very good idea of the weather during the winter and following summer of 1936. It will be noted that from March to August, inclusive, the average excess temperature per month was 2.6°F. and that during the six months there was a total of 7.77 inches of rain less than normal.

TABLE I. COMPARATIVE MONTHLY WEATHER DATA FOR INDIANA, 1936

Month		Temperature		Precipitation		Number of Days		
		State Mean	Departure from Normal °F.	State Average Inches	Departure from Normal Inches	Clear	Partly Cloudy	Cloudy
1935								
	Normal	42.4		3.06		11	7	12
November	1935	42.2	−0.2	3.52	+0.46	6	5	19
	Normal	32.1		2.86		9	7	15
December	1935	25.6	−6.5	1.61	−1.25	6	8	17
1936								
	Normal	29.0		3.03		10	7	14
January	1936	22.4	−6.6	1.47	−1.56	9	7	15
	Normal	30.3		2.41		9	7	12
February	1936	22.5	−7.8	2.59	+0.18	10	7	12
	Normal	40.6		3.75		10	8	13
March	1936	44.6	+4.0	2.74	−1.01	12	10	9
	Normal	51.8		3.49		11	9	10
April	1936	47.8	−4.0	3.17	−0.32	10	9	11
	Normal	62.2		4.01		13	9	9
May	1936	65.8	+3.6	2.02	−1.99	19	8	4
	Normal	71.5		3.76		14	10	6
June	1936	71.8	+0.3	1.37	−2.39	18	9	3
	Normal	75.7		3.31		16	10	5
July	1936	81.4	+5.7	1.59	−1.72	17	11	8
	Normal	73.5		3.38		15	10	6
August	1936	79.4	+5.9	3.04	−0.34	18	9	4
	Normal	67.2		3.42		15	7	8
September	1936	70.7	+3.5	4.84	+1.42	13	9	8
	Normal	54.8		2.77		15	7	9
October	1936	55.1	+0.3	4.44	+1.67	14	6	11

Field Crop Insects

The chinch bug (*Blissus leucopterus* Say) continues as a menace to small grain and corn, in spite of the low carry-over and the rather high winter mortality of 50%, as determined in surveys made by the U. S. Bureau of Entomology and Plant Quarantine. In exposed situations the mortality was as high as 98%. The bugs became active in grass clumps, April 14, when the air temperature reached 77°F. Migration to small grain started soon thereafter, and when the first few eggs were found May 19, all bugs had left winter quarters. Spring conditions were favorable to establishment and increase in small grains, resulting in scattered local damage from migrations to corn at grain harvest time, the first migrations being observed about June 27. By July 10 many bugs were mature and flying. Summer heat and drouth

were favorable to early and successful development of the second brood bugs in corn, and by July 20 infestations were recognized as significantly heavy in many regions, especially in the two western tiers of counties from Lake on the north to Greene County on the south. The infestation was not general, but scattered outbreaks causing very noticeable reductions in corn yields occurred. In the area referred to above the bugs are in winter quarters in moderate numbers with prospects of moderate to heavy infestations if winter and spring conditions are favorable to them.

The Hessian fly (*Phytophaga destructor* Say) produced an unusually heavy late fall brood in 1935, in addition to the normal fall brood. Although the late brood suffered a very high winter mortality, because they did not succeed in completing their larval growth before cold weather, there were enough flies surviving from the normal fall brood to produce a very heavy spring infestation in southern and western Indiana. The extreme heat and drought caused a high summer mortality of the puparia, and this, together with the general late sowing of wheat, resulted in a generally light 1936 fall infestation. The rains of late August and early September in northern Indiana, however, were rather favorable to growth of volunteer wheat and fly activity. As a result, in such areas the fall brood of fly is rather abundant in volunteer wheat which may serve as the source of considerable infestation next spring.

C. M. Packard, in charge of the U. S. Cereal and Forage Insect Laboratory at Lafayette, who has made a careful and detailed study of the Hessian fly problem, provides the following figures which illustrate the significance of the Hessian fly problem in Indiana (Table II).

Fungus gnats (*Sciara varians* Joh. det. A. Stone) were exceedingly abundant in wheat fields during April, leading many growers to confuse them with Hessian flies and to consider plowing under wheat.

TABLE II.

Year	Wheat Yield	Loss in Bushels	Loss in Dollars
1929	25,909,000	2,015,000	$2,256,000
1930	28,527,000	1,076,000	764,000
1931	44,544,000	1,072,000	482,000
1932	23,502,000	3,738,000	1,607,000
1933	22,905,000	622,000	535,000
1934	32,152,000	1,228,000	1,056,000
1935	28,618,000	3,672,000	2,790,000
1936	27,720,000	2,486,000	2,362,000
Total 8 years	223,877,000	15,909,000	11,852,000
Average per year	29,233,000	1,989,000	1,482,000

Armyworms (*Cirphis unipuncta* Haw.) were of little importance during the past year.

Corn earworm (*Heliothis obsoleta* Fab.) was generally scarce in corn until late August, although on July 17, seven of 12 ears of sweet corn grown near Lafayette were infested with worms from very small to nearly full grown. Beginning in late August, when eggs became very abundant on corn silks at Lafayette, the infestation increased rapidly, until at harvest time nearly all ears of field corn showed some infestation at Lafayette. Similar increases were noted in many other parts of the state. In the southern half of the state, tomatoes, green beans and peppers were generally infested during the last two weeks in September.

European corn borer (*Pyrausta nubilalis* Hbn.) suffered a decided set-back in 1936, similar to the high mortality resulting from the heat and drought of 1934, the reduction in the infestation in Indiana ranging from 40 to 70%. According to studies made by the federal entomologists, it is likely that the central region of Indiana is a transition zone between the present one-generation area and what will likely become a two-generation area in the southern half of the state. This, together with abnormal seasons in recent years which are unfavorable to corn-borer increase, may explain the slow spread through the transition zone. Scouting in Indiana added but one county, Johnson County, to the infested area.

Grasshoppers (*Melanoplus mexicanus* Sauss, and *M. bivittatus* Say) were destructively abundant in many counties of the state. Damage to field crops, including alfalfa, wheat, soybeans, cowpeas, and corn, was first reported June 14 from St. Joseph, Elkhart, and several adjoining counties, *M. mexicanus* being the predominant species. A little later they became generally common and destructive in several central western counties, including Tippecanoe, Benton, and Vermillion. As the heat and drought dried up succulent vegetation, especially that on idle land where they were abundant, the hoppers migrated to cultivated crops causing scattered damage throughout the state and rather general abundance in some counties. Damage to garden vegetables, including tomatoes, was not uncommon, and one reporter from Cass County reported defoliation of a young apple orchard. Grasshoppers are definitely on the increase and may be expected to be more generally abundant in 1937.

Sod webworms (Crambidae) were reported as damaging corn in several localities in northwestern Indiana the first half of June.

White grubs (*Lachnosterna* spp.) were responsible for scattered damage to grass and corn in the northern third of the state.

Common stalk borer (*Papaipema nitela* Guen.) was noticeably abundant, attacking corn and tomatoes at scattered localities about the middle of June, at which time the borers were quite small, not over one-half inch.

Clover leaf weevil (*Hypera punctatus* Fab.) damaged clover in central and eastern Indiana during the first half of May.

The overflow worm (*Agrotis ypsilon* Rott.) was again destructive to corn in the bottom lands along the Wabash River from Terre Haute south and along the Ohio River near Evansville, during June.

Vegetable Insects

Mexican bean beetle (*Epilachna varivestis* Muls. = *E. corrupta*) following mild winters and favorable seasons, spread and increased to destructive numbers the past two years in most regions throughout northern Indiana. The severe winter following was responsible for a very high mortality. The beetles were first observed at Lafayette, May 27, and during June showed signs of becoming extremely abundant. However, the intense heat in July caused a high mortality from which they did not fully recover, although they became fairly common in late fall. Observations the past ten years indicate that this pest will be a major annual pest in southern Indiana but that it will not be a problem in the northern third of the state, excepting following one or two mild winters and then only when the insects are abundant in the fall in southern Indiana and migrate in numbers to northern Indiana.

Bean leaf beetle (*Cerotoma trifurcata* Forst.) was reported damaging garden beans in many sections of the southern half of Indiana, most reports being received May 11 to 14.

Colorado potato beetle (*Leptinotarsa decemlineata* Say) was normally abundant throughout the state. Adult beetles damaged tomato plantings at Frankfort the last of May.

Potato flea beetle (*Epitrix cucumeris* Harr.) was a potato pest early in June in several localities in southwestern Indiana. Pale-striped flea beetle (*Systema taeniata blanda* Melsh.) was abundant and destructive to tomato plantings throughout the northern half of the state June 8 to 22. This species was also destructive to field and sweet corn in northern Indiana, although one report was from North Vernon in southeastern Indiana. The striped flea beetle (*Phyllotreta vittata* Fab.) was destructive to alfalfa at Winamac June 10.

Blister beetles (*Epicauta marginata, E. pennsylvanica*, and *E. vittata*) were abundant in gardens in early July, attacking potato, swiss chard, beets, and other vegetable crops.

Rhubarb curculio (*Lixus concavus* Say) was reported damaging rhubarb during the period May 13 to June 24, from many localities in the northern half of the state, one exception being Bedford in southern Indiana.

Zebra caterpillar (*Mamestra picta* Harr.) was abundant on garden peas at Fort Wayne, June 16, and riddling gladiolus foliage at Greenfield, June 15. In both cases the caterpillars were quite small.

Tomato worms (*Protoparce quinquemaculata* Haw. and *P. sexta* Joh.) became abundant during September, attacking both fruit and foliage of tomato in most regions of the state.

Cabbage worms (*Ascia rapae* L. = *Pieris rapae*) were unusually abundant this fall. The cabbage looper (*Autographa brassicae* Ril.) became abundant and destructive in August and early September, but were later checked by a bacterial disease.

Cabbage maggot (*Hylemyia brassicae* Bouché) was reported damaging cabbage at Indianapolis June 2.

Melon aphid (*Aphis gossypii* Glov.) was abundant in northern Indiana the last of August.

Turnip aphid (*Aphis pseudobrassicae* Davis) was abundant and destructive to turnips in the eastern part of the state during September.

Squash bug (*Anasa tristis* Deg.) was reported damaging squash at Roachdale, July 3.

Onion thrips (*Thrips tabaci* Lind.) was reported damaging onions at Ligonier, June 16.

The leafhopper (*Cicadula divisa* Uhl.) known to spread the causative virus of aster yellows and celery yellows, was found in noticeable numbers at Logansport, resulting in an appreciable amount of celery yellows.

Root-knot nematode (*Heterodera radicicola* Greef) is being brought into Indiana in increasing numbers on tomato plants originating in southern states. The problem is one deserving careful study and, therefore, in cooperation with the Botany Department of the Purdue University Agricultural Experiment Station, a study was inaugurated in 1936 to determine the effect of nematode infestation on productiveness, relation of infestation to tomato diseases, varietal resistance, and the ability of the pest to live over winter under Indiana conditions. The preliminary studies conducted in 1937 point to this pest as a factor of significance in tomato production.

Fruit Insects

The periodical cicada (*Magicicada septendecim* L.) appeared as anticipated over the greater part of Indiana, being especially abundant in the southern half, gradually diminishing in numbers towards the northern end of the state. At Orleans on April 10, skunks were observed to be very active in an apple orchard digging for cicada nymphs. Beneath the older trees (25 to 40 years old) 50 to 100 holes made by skunks in search of nymphs were counted, but rarely a hole beneath trees set out since 1919. The skunks, in their search, had dug 4 to 6 inches for the nymphs, which were 4 to 7 or 8 inches below the surface, although they had completed their exit burrows to near the surface. Apparently, the severe winter had no harmful effect on the nymphs. At Orleans the first adults were observed May 20, the first "singing" May 21, and the first egg laying May 26 or 27, and by June 3 broken twigs were conspicuous. At Lafayette the adults were first observed May 23. A fungus disease (*Massospora cicadina* Peck) was not uncommon attacking adults in some localities, although it was not of material value in controlling the cicada.

In southern Indiana many apple trees set out this past spring or the year before were severely damaged, and the egg scars on older trees were not uncommon and will serve as a protection for the San Jose scale against dormant sprays.

Scurfy scale (*Chionaspis furfura* Fitch) was reported from many localities in the state as abundant on apple trees which had not received the dormant spray.

Codling moth (*Carpocapsa pomonella* L.) carried over the winter of 1935-36 in comparatively few numbers, the lightest for several years, due to unfavorable conditions in 1935, and the severe winter which was responsible for a high mortality of those hibernating above the snow line. However, except for a few brief periods, the weather was favor-

able to the development of the codling moth during the 1936 season from the very beginning of spring, resulting in marked increases in codling moth populations. The codling moth carry-over this fall is very high, not only in southern Indiana, but also in regions of northern Indiana, especially where rigid spray schedules were not practiced.

The first overwintering larvae pupated at Elberfeld April 10, and at Bicknell April 13. By April 16, 50% of the overwintering larvae had pupated at Elberfeld and by April 23, 40% had pupated at Bicknell, according to the records of the federal Fruit Insect Laboratory. Emergence of adults began April 30 at Elberfeld; first moths were taken in traps at Bicknell May 4. At Orleans the first record of emergence was May 4, the first moths taken in packing shed May 5, and the first record at bait traps May 7, (May 8 in 1935). Bait trap records showed peaks of emergence at Vincennes and Bicknell May 16-17, and at Orleans May 16-18. In the northern half of the state our first bait trap records were as follows: Lafayette, May 16; Denver, May 16; St. Joe, May 16; LaPorte, May 20; Bristol, May 23. The first larvae were hatching in the Vincennes area May 14, and at Orleans May 21. First larval entries at Vincennes were observed May 19. First larvae left apples at Orleans June 8, and at Bicknell June 10.

By June 22 codling moth infestations were as abundant as for several years, in spite of a subnormal carry over. The first of the series of moth peaks for the second brood came June 21 at Orleans, with successive peaks June 30, July 6, 11, and 14, each being somewhat larger than the previous peak. The first third-brood peak came August 1, with successively larger peaks until the final and largest peak which came August 18.

Oriental fruit worm (*Grapholitha molesta* Busck) became rather conspicuous by the abundance of injured twigs by June 22. However, the absence of fruit in southern Indiana was unfavorable to fall development. In a few regions of northern Indiana where a peach crop developed, the fruit worm increased noticeably and is carrying over the winter in large numbers.

Spring canker worm (*Paleacrita vernata* Peck), appearing the last of May and early June, was more abundant and destructive in northern Indiana than for several years. Unsprayed apple trees were commonly defoliated, and elms especially, among the shade and timber trees, were defoliated in many localities.

Plum curculio (*Conotrachelus nenuphar* Hbst.) was reported by Steiner as more abundant than usual and doing considerable injury. At Vincennes, egg punctures were observed as early as May 5, only a few days after petal fall.

Apple curculio (*Tachypterellus quadrigibbus* Say) was more abundant throughout the state than for many years.

Apple flea weevil (*Orchestes pallicornis* Say) was active in southwestern Indiana as early as March 31, according to Ackerman, the adults being active in apple buds at that time.

Japanese beetle (*Popillia japonica* Newm.) was found in two new localities in Indiana by federal scouts. At Fort Wayne three beetles were taken in the bait traps, and at South Bend two beetles were taken. In

both cases the beetles were taken in the vicinity of railroad yards, indicating introduction by means of rail transportation. Besides these two places and Indianapolis, where beetles have been taken for the past three years, trapping was done in seven other Indiana cities.

Shot hole borer (*Scolytus rugulosus* Ratz.) was destructive to weakened stone-fruit trees, but was not as conspicuous as anticipated, perhaps because many of the peach trees died or were so weakned by the severe winter that they were pulled out.

Apple leaf skeletonizer (*Psorosina hammondi* Ril.) became very conspicuous late in the summer in apple orchards which had been poorly sprayed.

Apple leafhoppers (? *Tyhlocyba pomaria* McA.) were abundant the past fall on apple throughout the state. These pests are becoming more of a problem each year, and the evidence this year indicates that they are factors of considerable significance in reducing the size of fruit. In addition to damaging the foliage and, in consequence, the size of the apples, these insects are responsible for considerable spotting of the fruit.

San Jose scale (*Aspidiotus perniciosus* Comst.) suffered a high mortality during the past winter but has increased very noticeably in most sections of the state during the past season.

Black cherry aphid (*Myzus cerasi* Fab.) was very abundant and destructive to sweet cherry in orchards at Bristol, when visited June 19. Reports indicate their abundance in other parts of the state.

Cutworms (*Eriopyga cynica* Gn.) were reported to be attacking apple and peach buds at Bristol on May 15 and causing damage to the extent of $2000.00 in one orchard investigated.

Red spider (*Tetranychus telarius* L.) was reported damaging blackberry at Mt. Vernon, June 26, and dahlia at Warsaw, September 11.

Shade Tree and Ornamental Shrub Insects

Cottony maple scale (*Pulvinaria vitis* L.) began showing up in conspicuous abundance in the northern half of Indiana during June, the first time for some years that this scale has been conspicuous. Eggs began hatching in northern Indiana June 22. Severe winter apparently had no harmful effect on this insect.

European elf scale (*Gossyparia spuria* Mod.) was also abundant in many sections of northern Indiana. This species, apparently not checked by the winter cold, is increasing in importance as an elm pest. The young were hatching at Jonesboro June 27.

Oyster shell scale (*Lepidosaphes ulmi* L.) is another scale insect which was not affected by the severe winter weather in spite of the fact that it is in a fully exposed situation. At Lafayette the young were hatching May 20, much earlier than usual.

Elm scurfy scale (*Chionaspis americana* John.) and pine leaf scale (*C. pinifoliae* Fitch) were normally abundant, the winter apparently having had no harmful effect.

Arbor vitae scale (*Lecanium fletcherii* Cock.) was reported by Rippey as on the increase and very abundant on arbor vitae in nurseries in northern Indiana.

Elm cockscomb gall (*Colopha ulmicola* Fitch) was reported as abundant from many parts of Indiana.

Elm leaf beetle (*Galerucella xanthomeloena* Schr.) was reported as defoliating large elms near Corydon. This is the first authentic record we have had since we began keeping records of Indiana insects in 1920. This is the third consecutive year of defoliation according to our informant. Later in the year word was received of defoliation of elms by this insect at Richmond.

Elm pine shoot moth (*Rhyacionia buoliana* Schiff. Heinrich det.) was rather common previous to July 20 on Mugho pine plantings at South Bend.

A sawfly (*Neodiprion* sp. Middleton det.) was reported attacking pines, including Scotch pine, at South Bend and Fort Wayne.

Flat-headed borer (*Chrysobothris femorata* Oliv.) was a common pest of maple, apple, and elm in many parts of the state, most of the reports being received during July.

The bagworm (*Thyridopteryx ephemeraeformis* Haw.) and tussock moth (*Hemerocampa leucostigma* S. & A.) were normally abundant in southern Indiana. At Terre Haute both species were hatching by May 31, at which time the worms were only a day or two old.

The American bark beetle (*Hylergopinus rufipes* Eichh.) was taken from an elm log in the vicinity where Dutch elm disease was found in Indianapolis this fall, according to Rippey. Specimens were sent to the Dutch Elm Disease Laboratory where the beetles were used in experiments and successfully established the disease on healthy elms.

Rose sawfly (*Caliroa aethiops* Fab.) was reported abundant on rose in several localities in the state during June and early July.

Lawn and Flower Garden Insects

Larvae of the green June beetle (*Cotinis nitida* L.) were reported damaging lawns in extreme southern localities in Indiana. At Evansville, according to a report received August 25, the parasite (*Scolia dubia*) was conspicuously abundant.

Ants (*Formicidae*) were common in lawns in many localities in the state, especially during May.

White grubs (*Lachnosterna* spp.) were damaging to lawns in isolated locations in northern Indiana.

Bronze cutworm (*Nephelodes emmedonia* Cram.) damaged blue grass lawns at Aurora, according to a report received May 19. However, this cutworm was not observed to attack adjoining plantings.

Household and Annoying Insects

Termites (*Reticuliternes flavipes* Koll.) continue as one of the major destructive insects in Indiana. This past year swarming was first observed in January and was more or less continuous in different locations until April 26.

Although termites must be recognized as a major destroyer of property, exaggerated statements have instilled unwarranted fear in the minds of many home owners. This in turn has provided easy work for racket and itinerant operators. There are reliable and experienced

termite control operators in Indiana, but there are many more who practice termite control who are wholly incompetent. Only persons or firms of known reliability should be employed for protecting homes from termites.

Powder post beetles (*Lyctus* spp.) are very common pests of hickory furniture, log cabins, and timbers in homes and barns throughout the state.

Cluster fly (*Pollenia rudis* Fab.) was frequently reported as annoying in homes in the northern half of Indiana during March and April.

Mosquitoes (Culicidae) were abundant and annoying in many localities in the state the middle of May and also during June.

Bedbugs (*Cimex lectularius* L.) have been reported abundant in homes and poultry houses in many localities in the state.

Other insects commonly reported as annoying or destructive in the home included the following: ants (Formicidae), fleas (*Ctenocephalus felis* Bouché), cockroaches (Blattidae), silverfish (*Lepisma saccharina* L.) clothes moth (*Tinea pellionella* L.), carpet beetles (*Attagenus piceus* Oliv. and *Anthrenus scrophulariae* L.) and boxelder bug (*Leptocorus trivittatus* Say).

Stored-Grain Insects

Angoumois grain moth (*Sitotroga cerealella* Oliv.) was frequently reported during May infesting seed corn and popcorn, most of the reports coming from the southern half of the state and in corn held over the second year.

The usual number of inquiries were received regarding the bean weevil (*Mylabris obtectus* Say), granary weevil (*Sitophilus granaria* L.), confused flour beetle (*Tribolium confusum* Duv.), saw-toothed grain beetle (*Oryzaephilus surinamensis* L.) and Indian meal moth (*Plodia interpunctella* Hbn.).

Orthogenetic Variation

CHAPMAN GRANT, San Diego, Cal.

Hans Gadow was the author of a contested hypothesis called "orthogenetic variation." This endeavored to account for an apparent reduction in the number of extra scutes during the growth of turtles. This paper presents later evidence which may prove that some of his assertions were correct, and at the same time it may reconcile a few of the arguments advanced by Gadow's critics.

To orient the reader, it might be said that, except in a few species of turtles, the normal horny scales or scutes covering the bone case or box are arranged and usually designated as shown in Figure 1. Scutes in excess of this complement have been called "extra," "supernumerary," "abnormal," or, as Gadow believed, "atavistic." In this article the scutes will be termed "extra" and the turtles bearing them "abnormal." We do not deny the existence of atavistic scutes, and by "abnormal" we mean only variations from the average.

In arriving at his theory of orthogenetic variation, Gadow (1) studied and tabulated the scutes on a series of 82 marine turtles and showed that the young had from four to seven times as many extra scutes as the adults. For some reason he did not blame the possible handicap caused by abnormalities for the destruction of individuals by their natural enemies. He stated, in so many words, that natural selection remained indifferent in this case. To explain the apparent reduction of extra scutes on growing turtles, he evolved the idea that the individual lost them by: (a) fusion of two or more scutes; or (b) suppression of a scute by its failing to grow amid normally growing scutes. He admitted having no evidence to prove this and said that it would be necessary for some one to watch the growth of marked turtles to prove his theory. In the meantime he said that he appealed to common sense and comparative anatomy to uphold him. He stated: "I therefore call this kind of atavistic variation orthogenetic." Literally that would mean that a turtle is an atavistic variant only as long as it retains extra scutes. He desired a term descriptive of self-correction by an individual while dropping ancestral traits and approaching the so-called normal. He did not use "variation" in its commonly accepted meaning. He might have said, "I therefore call this changing from atavistic toward normal, an orthogenetic change, or orthogenesis." The term "ontogeny" might have been used.

Coker (2) rebutted Gadow's hypothesis by calling attention to the small series of specimens used by Gadow and to the fact that the two largest specimens bore the greatest number of scutes, which would tend to refute his hypothesis at the start. Also there were 44 abnormals from one nest of 47 babies in the total series of 82. Coker submitted a table of 238 specimens of Malaclemmys and said that the percentage of abnormals did not vary with age but that extra or abnormal scutes might be correlated with deep-seated abnormalities which could cause death. Coker did not point out that symmetry was not so vital to palustrine Malaclemys as it would be to a marine turtle in its exacting environ-

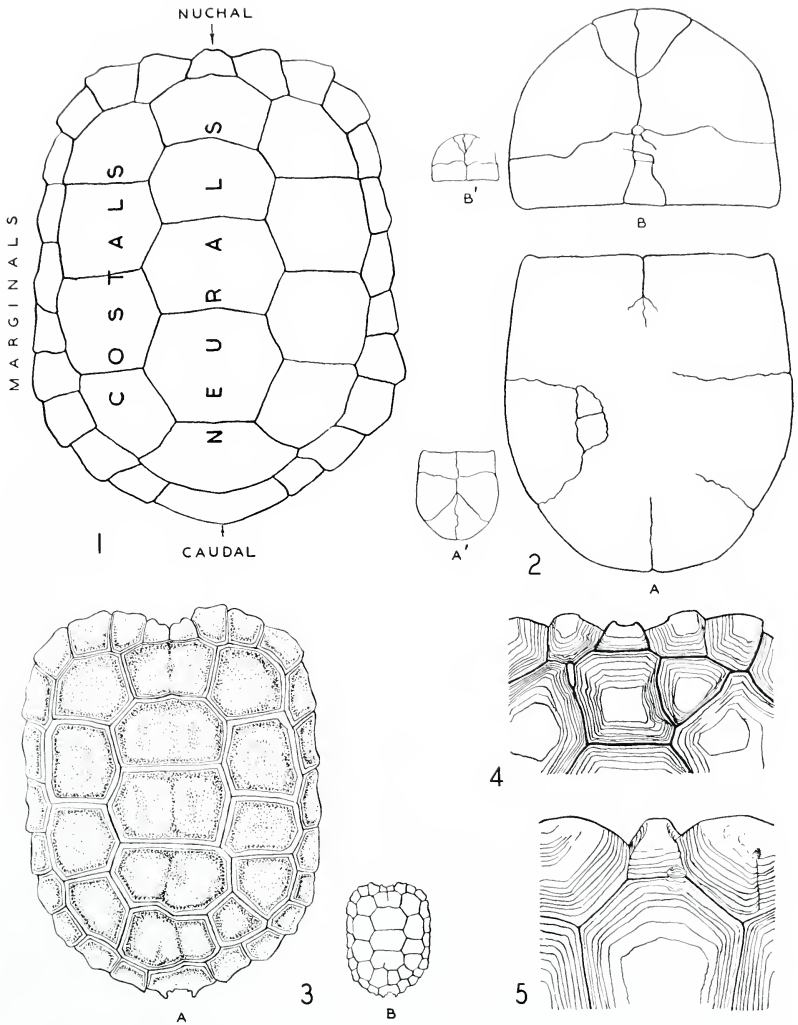

Fig. 1. Normal scutes of carapace of *Gopherus agassizii.*

Fig. 2. *A*, posterior lobe of plastron of *Terrapene triunguis* (13,165, Field Museum), showing that the normal sutures as shown in *A'* have disappeared or wandered, making false scutes; *B*, anterior lobe of plastron of *T. carolina* (18,649, Field Museum), showing that normal sutures as shown in *B'* have wandered and thereby formed false scutes.

Fig. 3. Yearling of *G. agassizii. A* shows that some sutures did not develop although they had been indicated by aeroles when the specimen first hatched as shown in *B* by the split nuchal, and first, fourth, and fifth neurals. Note the double ocellation in the second and third neurals indicating a primordial double row. Specimen alive in writer's possession.

Fig. 4. Anterior portion of carapace of *G. agassizii*, showing an extra costal, anterior to number one on the right side, and a corresponding scute on the left which is being crowded out. Specimen alive in writer's possession; presented by Dr. F. B. Sumner.

Fig. 5. Anterior portion of carapace of *G. agassizii* showing extra scute, which is being crowded out at the right rear of the nuchal. This may have originated as a split nuchal, as in Fig. 3. Note the "radial suture" on the first right marginal. Specimen dead in possession of writer.

(Illustrations by Norman Bilderbach, by courtesy of Dr. C. G. Abbott, San Diego Soc. Nat. Hist.)

ment, nor did he state whether his examples were reared in capitivity or had been wild specimens exposed to normal dangers. Lastly, his oldest specimens were only three or more years old. He then took up "fusion and division" which had been Gadow's next point and illustrated his article with specimens of partial fusion and partial division and ended by saying that finally there is no actual fusion or division at all. We shall see in Gadow's next paper that he thought Coker had admitted fusion. He evaded Gadow's idea of a crowding out or suppression of scutes by saying that where the outer scute layers scale off, the record of a scute which had not developed would be obscured and that such cases are unexplained and probably abnormal. We believe that scaling off of outer layers of scutes is normal in Chrysemys and explained as the usual shedding of a reptile skin. To clinch his argument Coker stated that sutures remain distinct. We have found that sutures sometimes wander or disappear in old turtles as described with Figure 2.

Gadow (3) later, in 1905, disputed Coker and championed the term "orthogenetic variation," for which he claimed authorship. He admitted that his specimens had been too few, but said that Coker's were too young—largely embryos. He stated that Coker had charged him with the claim that embryos "should begin to mend their ways before they are born" and denied the assertion, although in his first paper he had said: "In several newborn specimens such a fusion is still incomplete." This remark might lead to the assumption that he believed in embryonic scute fusion; so it is not clear why he was so ready to deny it. He seized upon Coker's remarks on fusion by saying: "Would it not . . . support my hypothesis . . . that the number (of scutes) can be reduced? I should feel grateful (to Coker) and glad to accept 'fusion' instead of my suggested 'squeezing out'." As has been pointed out, Coker did not admit of a fusion of scutes "once formed," but we do not understand what Coker meant by "once formed" as no question is likely to arise about unformed scutes.

Coker (4) still later, in 1905, regretted that Gadow had misinformed unsuspecting readers of Volume 8 of the 1901 Cambridge Natural History by saying that certain shields are squeezed out or suppressed by their enlarging neighbors and that the ultimate result is the formation of fewer but larger shields. We point out later that Gadow was probably correct, but he had no proof for his statements.

Newman (5) summarized Gadow's work and stated that he could see no difference in proportion of abnormals between young and adults in his series of 476 specimens of Graptemys and 188 of Chrysemys. He stated that a scute, whether normal or extra, is a separate and definite entity, resulting from a definite embryonic primordium. The writer cannot fully subscribe to this statement. A scute is not an organ, but merely an epithelial area of a size first dictated by the necessity of pliability, and later, as turtles developed a bony box, the reduction of the number of scutes was limited by the necessity of enlarging to keep a growing box covered. Newman criticised Gadow's tables by saying that a large proportion of new-born specimens came from one nest, the whole brood of which was abnormal and that the others were taken in small sets from various collections and he believed that such specimens had been

preserved chiefly because of their abnormalities. Neither Newman nor Coker made allowances for the higher mortality of prolific sea turtles. This point would have mitigated some of Gadow's statements, although he checkmated himself with the statement that natural selection remained indifferent to abnormalities.

Parenthetically, the writer wonders at the statements of Gadow that natural selection remains indifferent to an abnormality and of Coker and Newman who subscribe to the same idea when they unqualifiedly state that they found no difference in proportion of abnormals among young and adults. Coker (2) said that it was hardly conceivable that the success of a turtle in the struggle for existence would hinge on whether it was the possessor of ten or eleven costal scutes. He went on to say that probably extreme cases were correlated with deep-seated abnormalities which might cause failure to survive and that natural selection could not be ignored. Such statements and findings seem tantamount to professing belief in creation and abjuring evolution. The writer believes that an infinitesimal variation is immensely important in geological time. Authorities supposedly agree that the ancestors of turtles had more scutes and that the survival of the fittest evolved the present form. Since atavism is an established fact, some extra scutes on turtles may prove to be atavistic. Variation must be constant and radial or the living universe would be static; consequently variations of even less than the present normal number of scutes should be expected. The fittest have always survived in the long run; so it is impossible to believe that individuals with either more or less than the normal number of scutes should have the same chance of survival as the normal. The "normal" may be shifting to more or less scutes than we now consider normal, but it would take years and great numbers of specimens to prove this.

Coker (6) stated that external pressure on soft turtle eggs might cause abnormalities. The present writer found that about 10% of over 300 specimens of Gopherus examined were abnormal, but the eggs of this turtle are brittle and so hard as to be insusceptible to warping by any pressure they would normally receive. Coker reviewed all the authors who wrote about extra scutes and summarized Gadow as follows: (1) Variations are reversions to ancestral conditions. (Parenthetically let us point out that Gadow (3) had stated that there is also a "beyond the type," meaning a variant with less than the normal number of scutes.) (2) The hypothetical explanation is that these atavisms are stages in ontogeny or arrests of development.

Coker said that when Gadow regarded these atavisms as arrested development in adults and ontogenetic recapitulation in the young, his position seemed untenable on the basis of any facts then at hand. However, Coker discussed radial sutures appearing in the periphery of abnormally large scutes by saying that these radial sutures may indicate post-natal attempts to perfect a previously inadequate adjustment. This is apparently just what Gadow meant in his hypothesis and what Coker was endeavoring to discredit.

We believe that these radial sutures are caused by a purely mechanical law which is here discussed. Theoretically, one single horn scute would have been the turtle's ideal covering, but horn, being dead, cannot

stretch; so it was impossible for all the scutes to fuse into one sheet and keep the box covered as it grew. Mechanically there was a minimum number of scutes below which evolution could not go. In terms of geology a cooling, shrinking magma splits into hexagonal pillars, similar in cross section to the scutes of a turtle. An example more frequently seen is in the hexagonal cakes formed in drying mud. An interesting analogy is the "turtle stone" formed when the cracks of dried mud are filled with sand and the whole solidified and later broken and rounded by the elements. Growth from within or radial expansion is the opposite of the geological phenomena mentioned, but the result is the same. Now if it were possible to remove the scutes from a young turtle and cover it with a brittle unyielding substance, its growth would probably crack this coating into figures similar to normal scutes. The numerous marginals cannot efficiently reduce further because the plan and cross section of a turtle change, the hatchling being flatter and more nearly circular than the adult. Since the greatest change of shape occurs along the margins, smaller scute units are required to accommodate it. A like explanation for the growth of the plates of the inner bone box is not necessary because bone grows by introsusception, whereas dead horn cannot. The turtle early found the smallest number of scutes which could cover the bone case and still accommodate growth. The radial sutures which Coker mentions as post-natal efforts to carry out a plan may have been mechanical adjustments based on a law of minimum sutures or fractures.

The figures may serve to coordinate some of the above views.

Figure 2 is of two aged specimens of Terrapene in the Field Museum. The plastrons are greatly worn. The writer's interpretation is that with age and the consequent cessation of expansion, the normal growth stimuli of the malpighian layer are changed fortuitously, allowing the sutures to wander or disappear. If this interpretation be correct, sutures are not always fixed, especially when they disappear altogether, as in Figure 2, A, *T. triunguis* (No. 13,165). The extra areas which have appeared, as in Figure 2, B, *T. carolina* (No. 18,649), by reason of the fortuitous wandering of the senile sutures should not be classed as scutes, being merely divisions that were not represented by the original aeroles. Figures 2, A′ and B′ show the normal sutures on the plastron of a vigorous specimen.

Figure 3 is of a baby specimen of *G. agassizii* which the writer saw hatched. Figure 3, B, which was made at the time of hatching, shows a double aerole at the rear of the neural series. The quadrangular scute at the rear of the fourth neural can be considered as the sixth right costal because there is a faint indication of the fifth neural to show pairing or longitudinal division as in the nuchal. Figure 3, A, shows the same specimen at the age of one year. Two aeroles, or the last neural, developed as one unit, appearing to prove Gadow's assertion of loss by fusion. The writer believes that it shows an atavistic scute, but no growth was needed at the extra suture to comply with the law of minimum sutures. This case is altogether different from Coker's theory of partial fusion of scutes once formed.

Figure 4 is of a 10 cm. female of *G. agassizii*, with about six growth

rings, which was presented to me by Dr. F. B. Sumner. This specimen has a medium sized extra scute between the first costal and first neural on the right side. At a corresponding position on the left side, there is a narrow scute which I interpret as having been a very small original aerole that did not increase in size. It may have grown higher from successive layers of horn having been deposited underneath and then broken off by some mechanical agency. This narrow, slit-like area, which probably was a well marked aerole in the hatchling, is seemingly disappearing, thus reducing by one the number of original aeroles and proving Gadow's hypothesis of "suppression" of extra scutes.

Figure 5 is of an old specimen. It shows what the writer interprets to be the right half of a paired nuchal which did not expand, while the left half grew normally. What may have been the right half is now a high, wart-like process which could conceivably be broken off. Probably the aeroles of this specimen showed an evenly divided nuchal as in Figure 3. Normally the nuchal is single in this species.

Summary

1. The term "orthogenetic variation" as used by Gadow appears to be meaningless.

2. Turtles occasionally show fewer scutes when adult than appeared in the hatchling due to: (a) the development of two aeroles as one scute, (b) the failure of a small aerole to expand, resulting in its being crowded out by the normal development of adjacent scutes, or (c) the wandering or disappearance of sutures in aged turtles, thus obliterating the original scutellation.

3. In addition to the reduction of extra scutes mentioned in (2) above, a sufficient series must show a higher mortality in abnormal than in normal turtles.

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The "Midventral Keel" in Testudinata

CHAPMAN GRANT, San Diego, California

The origin of the Testudinata is much in doubt, but several scientists have reconstructed an ancestor from the evidence afforded by paleontology, embryology, comparative anatomy, and "atavistic" scutes.

Probably less has been written about the hypothetical undershell or plastron than about most parts of the turtle. However, in place of the midventral seam or suture common to reptiles, it was the belief of several scientists that there had been a single midventral row of bone plates covered by horn scutes on the plastron. In other words, if one could see the under shell of the ancestral turtle he would behold not a central seam or suture, but a central row of horny scutes or scales, possibly in the form of a tuberculated ridge or keel flanked by similar parallel keels, somewhat as is shown in Figure 1.

Newman advanced three theories to prove this. The first was that the midventral keel now found in the many-keeled leather-backed marine turtle is a remnant of an ancestral keel no longer found in other turtles; the second, that certain mid-areas under the tail-trunk of the snapping turtle were homologous to this midventral row; and the third, that single intergulars and the uncommon interplastrals of modern turtles were atavistic reminders of an ancient structure. Hay also believed in a midventral row, but advanced only the third point above mentioned.[1]

In order to show that it is probable that the ancestral turtle possessed a median seam or suture, as is the case in modern reptiles, and not a midventral row of bones and scutes, we must be able to account for the presence of a single midventral row of scutes in snakes, the midventral keel in the great marine turtle, and the occasional intergular and interplastrals of pond turtles, and then present such further evidence as we possess.

Snakes are the only reptiles which have a midventral row of scutes. These crawling reptiles are a comparatively modern development and can hardly be claimed to have had a common ancestor with the ancient turtle. There is sufficient evidence that the single ventrals and caudals of snakes are a fusion of several rows (Grant, 1935). Many species have a double row of scutes under the tail with a consequent median suture. The tail, having least to do with the gliding locomotion of snakes, would be expected to be the last place to retain a median suture, and that is exactly the case. One or more pairs of preanals in various species again remind one of a primitive central suture. Young snakes usually have several scutes divided at the midline at the umbilical

[1]Direct quotations from these writers follow: Newman (1906, W. 75): "The missing keel (of modern turtles) is the midventral one (of the leather-backed turtle)"; (p. 102): "Smaller and less regular rows of tubercles and scales (on the tail-trunk of the snapping turtle) are homologized with the secondary or lost rows (of turtle scutes) as follows . . . interplastrals (of the tail-trunk of the snapping turtle being homologous to the vanished interplastrals of the ancestral turtle.)"; and (p. 71; see also pp. 75, 81, 103, and 111): "Traces of a median ventral row of scutes are found normally in some species—I have given the name *"interplastral"* to this row. A single (anterior) median scute is named the *"intergular."* O. P. Hay (1898); "The great scutes of the plastron . . . grow toward the midline . . . they have suppressed the scutes of the middle keel."; and (Hay, 1928): "The median, or interplastral row of epithecal bones with their scutes, were early suppressed."

region. Occasional atavistic ventral scutes start from one side and stop at the midline. Other specimens have a notch or nick at the center of many of the ventrals. Newman (1906, p. 107, and note 6) has shown that color pattern is closely associated with the centers of existing or lost scutes in turtles. The same law probably holds true with snakes, as none have a median line of pigmented dots or marks, but many have parallel rows of dots or other markings, leaving the midline clear. This

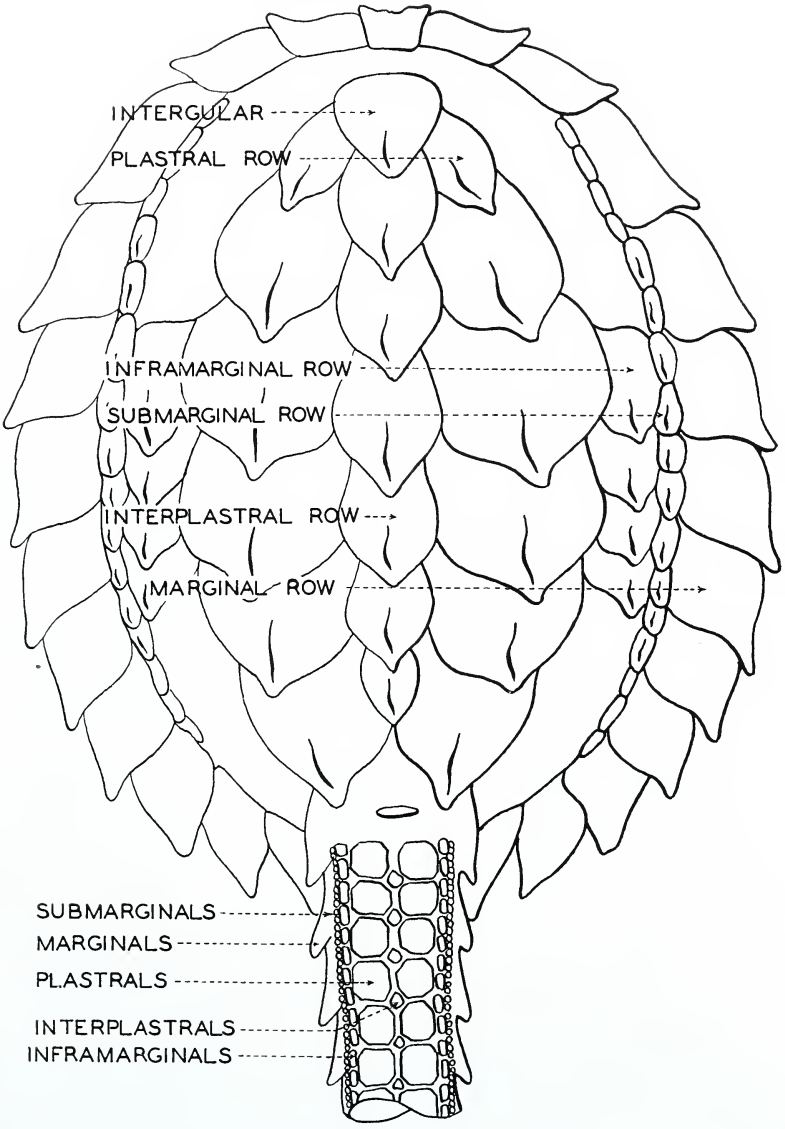

Fig. 1. A composite hypothetical plastron from various writers.

would indicate an ancestral suture flanked by several rows of scutes all of which have fused into the present wide ventrals of snakes. The snake, then, is the only modern reptile with a median row of scutes, and this development was probably coeval with limbless locomotion. All other reptiles have a median suture.

The midventral keel in Dermochelys, the leather-backed turtle, must be explained. It is difficult to imagine any reason for a terrestrial animal's having prominent ventral keels, especially an animal with the low clearance of a turtle. It seems reasonable therefore to believe that the leather-backed turtle developed its five ventral keels after becoming aquatic. Why a marine turtle should develop so many keels is possibly because all terrestrial quadrupeds normally progress by moving the front feet forward alternately with the diagonal hind foot. Pond turtles swim as they walk—diagonal legs moving in unison to hold their direction; but marine turtles swim with the fore flippers in unison, the hind flippers not being used in straight progression. Therefore, there must have been a time when the marine turtle was changing methods from swimming with alternate legs to its present system. If at any time it swam with alternate front appendages without a corresponding impetus from the diagonal hind ones its motion would have been oscillating. Keels would help overcome such an oscillation. The foregoing rather fantastic theory is given as much to call attention to the interesting problem of the different motions of the limbs of pond and marine turtles as to explain the presence of keels. A better reason for ventral keels might be for protection from attack from underneath. The hawksbill turtle has ventral keels, but not a median row or keel. The other marine turtles apparently learned to swim without keels or at least have not retained any trace of them. In the final analysis, as Baur (1888, p. 144) said, "Sea turtles have been developed in different places at different times . . ."; so an explanation for one genus might not hold for another.

To explain the origin of the central areas under the tail-trunk of *Chelydra,* the snapping turtle, it is noted that large scutes in reptiles seldom fit together in square points. Thus the square scutes of crocodilians have the tips rounded off and the resulting interstices filled by "pseudo-scutes" or merely criss-crossed skin. It has been shown (Grant,

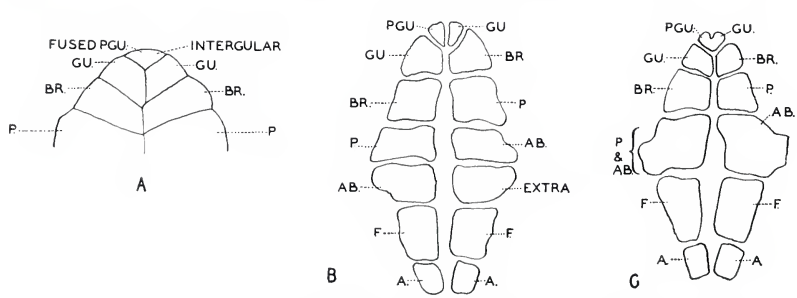

Fig. 2. Comparative interpretation of scutes. *PGU,* pregular; *GU,* gular; *BR,* brachial; *P,* pectoral; *AB,* abdominal; *F,* femoral; *A,* anal. The letters on the left of each figure are the writer's interpretation; those on the right are the interpretations of Coker in A, and Newman in B and C, from whom the figures are taken. The difference is due to the writer's naming the scutes from the center, whereas others name them from the anterior end, starting always with a gular.

1937) that the plastral scutes in very old turtles sometimes have their corners cut off as a result of meandering sutures, which gives the appearance of interplastrals. The so-called median row of scutes on the underside of the tail of the snapping turtle, which Newman (1906, p. 102) homologizes with the lost theoretical midrow of bones and scutes of ancient turtles, is apparently no more than "fillers" between approximately square scutes, developed because lateral flexibility is necessary and would be impeded if the scutes impinged with right angles to their very points.

The "intergular" (Figure 2, A) is a single scute which has been designated as evidence of a lost median row. Newman (1906, p. 71) thus defines it: "A single (anterior) median scute is named the 'intergular'." That is satisfactory for a definition, but later he says (p. 93): "Fig. . . . shows . . . the gulars have been fused into a single median element." This is correct, but his Figures 52 and 53, which are our Figures 2, *B* and *C*, show the "intergular" divided and partly divided respectively. In other words, the intergular has been derived from a pair of scutes. It seems strange that, having fused, the resulting element called the "intergular" should then be held to represent a relic of a single median structure. The writer submits the divided intergular as evidence of an original double row and not as a representative of a lost single row. Coker (1910, p. 3) says: "In 31 new-born green turtles . . . the normally unpaired intergular was in 6 specimens represented by a pair of scutes and in 9 others was partially divided." Sixteen out of thirty-one seems to be a small percentage to prove normalcy. In other words, when a single median anterior unit is found, it is called an "intergular" and is used as evidence of a prior single median row. It would seem well to say that the anterior elements or "progulars" actually represent a pair of scutes of the interplastral rows.

Interplastrals are referred to as atavisms of a single midventral row when they occur singly, but when they occur in pairs, nothing is said about it. Newman (1906, p. 81) says: "The primitive condition

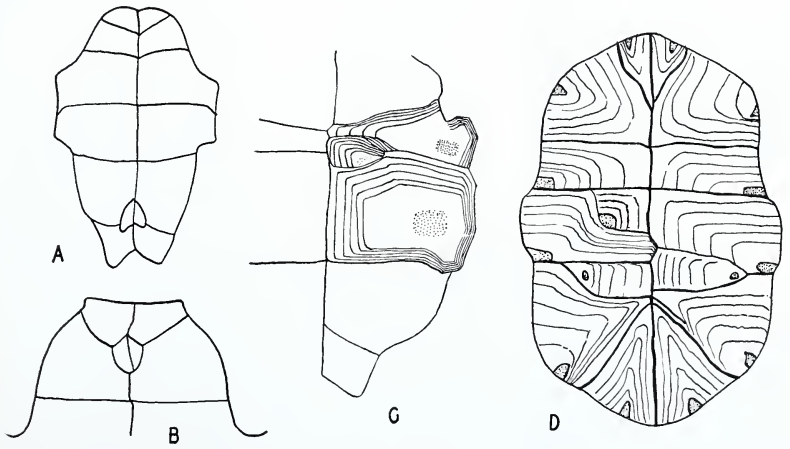

Fig. 3. Evidence of a double interplastral row. *A*, interfemorals; *B*, interbrachials; *C*, interpectoral; *D*, interabdominal and interfemorals.

was probably one in which a scute was present at each point of union of four plastral scutes." It is difficult to see how his "intergular" could qualify by fitting between four plastrals since it touches only the gulars. He illustrates with figures of specimens bearing extra scutes in four of the five possible symphyses, and, strange to say, one of his figures shows a *pair* of interplastrals, the rest showing only single ones (Fig. 3, A). We strengthen this evidence by two more examples with paired interplastrals (Fig. 3, *B* and *D*) and one single, but lateral, interplastral (Fig. 3, *C*).

The pectoral and abdominal scutes normally join or bridge the plastron to the carapace in pond turtles, as shown in Figure 3, A. The writer believes that this is the most logical place to start classifying the plastral scutes and that they should be identified from this point forward and backward. The diagrams in Figure 2 are lettered according to our interpretation on the left side and according to the writers from whom the diagrams are borrowed, on the right hand side. In Figure 2, *B*, we have labelled the bridge scutes pectoral and abdominal respectively, and in Figure 2, *C*, we consider that the large bridging scute is formed by fusion of the pectorals and abdominals. Counting forward from this point in Figure 2, *B*, we find the brachials and then the gulars. Anterior to the gulars is another pair of scutes which we consider to represent an earlier normal anterior pair of plastral scutes. Lacking a name we call them *progulars*. Newman interprets them differently. He begins anteriorly and, in Figure 2, *B*, names the anterior pair gulars, then follow brachials, pectorals, and abdominals, and then ". . . a well-developed pair of extra scutes between the abdominals and femorals . . .", femorals, and anals. In Figure 2, *C*, we consider that the most anterior element is formed from partly fused progulars, then gulars, brachials, fused pectorals and abdominals, femorals, and anals. Newman interprets them as beginning with partly fused gulars followed by brachials, pectorals, abdominals, femorals, and anals.

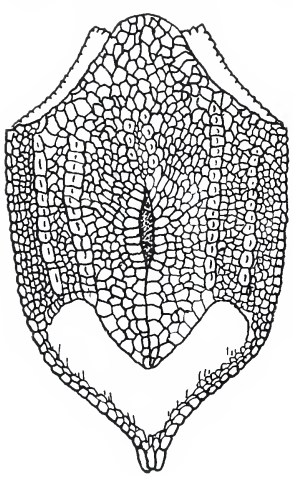

Fig. 4. Evidence that the midventral keel in the leather-backed turtle is postnatal. Newly-hatched young showing open umbilical scar and evidence that the keel is formed from the edges of this scar (after Stegneger, 1904).

Further evidence against a midventral row of scutes or a keel may be had by studying the structure of keels that occur elsewhere on turtles. Keels on the upper shell or carapace of turtles occur only over the center of a row of bony plates, and they are frequently underlaid by a row of bone ossicles which may have been the bone cores of the tuberculated keels. A midventral scute-keel on the plastron of a turtle would presuppose the existence of a central row of underlying bones, but none such is shown ever to have existed. Again, one might expect that a row of ossicles would designate the position where the tubercles had been, as they do on the carapace of several species, but, again, no such evidence exists. Furthermore, a midventral keel

means the formation of a scute-keel over a bone suture, and there is no such structure elsewhere on the turtle. The very nature of the development of a reptilian embryo is of a ventral suture which fuses, leaving a permanent seam, except in snakes, unbridged by bone or scute in the region of the umbilicus.

Finally, the midventral "keel" in the trunk-backed turtle is *postnatal* in development, as is shown in Figure 4, where the central keel is seen to be derived from the union of the thickened edges of the umbilical scar, which extends three quarters of the length of the plastron.

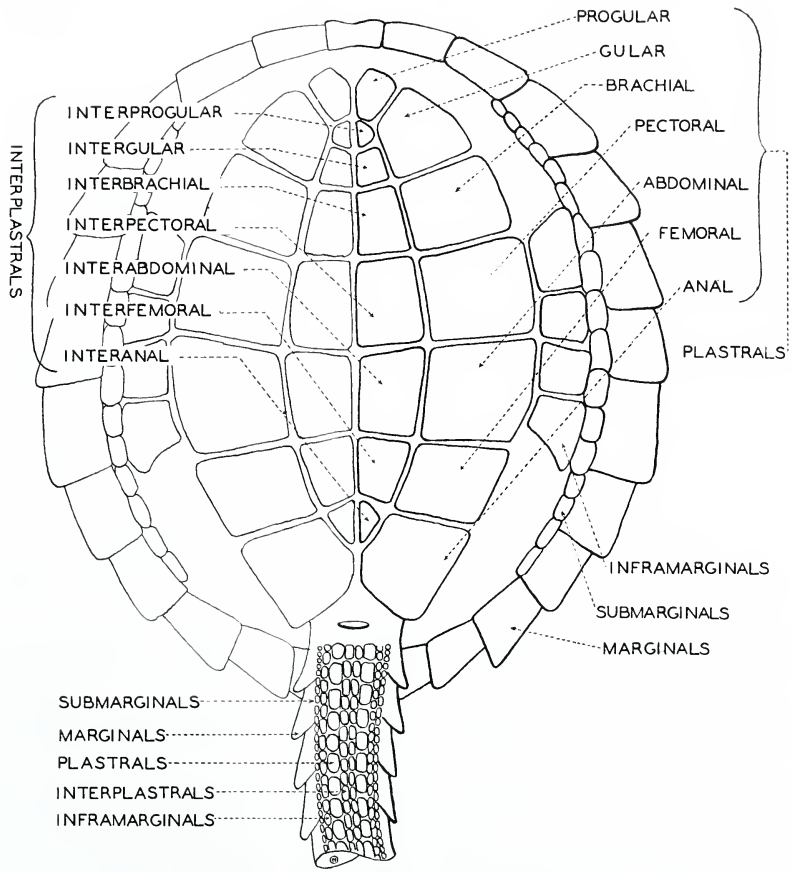

Fig. 5. Hypothetical plastron as reconstructed by the writer.

The writer believes that Figures 3, *A*, *B*, *C*, and *D*, show that there has been a crowding out, as Hay said, but that what was crowded out was a double row and not a single midventral row. He believes that an ancestral plastron and tail-trunk might have looked something like Figure 5 and recommends the adoption of the new nomenclature given in his figures wherever they add clarity. Comparing Figure 5 with Figures 2,

B and 3, it will be noted that actual examples are given for all scutes of the theoretical double interplastral row except the last interanal. It is expected that wider collecting may bring the missing case to light.

All the drawings used in illustrating this paper were made by Mr. Norman Bilderbach, by courtesy of Dr. C. G. Abbott, San Diego Society of Natural History.

Summary

1. The theory has been advanced that ancient Chelonians possessed a single midventral row of plates and scutes, based on the following evidence: the midventral keel in Dermochelys, the mid-areas under the tail-trunk of Chelydra, and the single intergular and uncommon interplastrals.

2. It is shown that, although the snake possesses a midventral row of scutes, this is a recent modification, that the midventral keel of *Dermochelys* is a post-natal modification of the umbilical scar, that the areas under the tail-trunk of *Chelydra* are pseudo-scutes or fillers, that the intergular is a result of the fusion of a pair of scutes, and that interplastrals are remnants of paired scutes.

3. It is shown that it is improbable, for structural reasons, that there ever was a midventral row or keel.

4. Figures are given illustrating the two hypothetical cases—the single-rowed plastron and tail-trunk and the double-rowed—also cuts showing the progulars and interplastrals and the umbilical region of a young Dermochelys showing the formation of the midventral keel.

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A New Second Intermediate host of the Trematode, *Gorgodera Amplicava*

W. E. Martin, Purdue University

Gorgodera amplicava Looss is a common trematode parasite of the urinary bladder of the frogs, *Rana clamitans* Latr. and *R. catesbeiana* Shaw. Krull (1935) has described the life cycle of this parasite. He found that a bivalve mollusk, *Sphaerium partumeium* Say, served as the first intermediate host and that a snail, *Helisoma antrosa*, acted as the second intermediate host. In a later paper, Krull (1936) lists the following additional snails that may function as second intermediate hosts: *Physa halei, Lymnaea traskii, Helisoma trivolvis,* and *Pseudosuccinea columella.*

To this list of second intermediate hosts I wish to add the crayfish, *Cambarus sp.* In the examination of these crustacea from a small stream near Lafayette, Indiana, a number of metacercariae were found in the body cavity, loosely attached to the wall of the cardiac chamber of the stomach. Over 50% of the crayfishes from this region were infested with this larval trematode. Clams of the genus *Sphaerium* were collected from this locality, and some of them gave off cercariae which were fed to crayfishes. The crayfishes used in the feeding experiment were part of a group collected from a very small stream in which no *Spaerium* or other bivalves could be found. As a check on previous infestation, approximately fifty crayfishes from this group were examined and found to be negative. The cercariae which were fed encysted in the crayfishes in the region of the cardiac chamber of the stomach. When crayfishes were examined at intervals after the feeding, it was found that the metacercariae reached their maximum size in four or five weeks. Crayfish tissue containing metacercariae was fed to two of four frogs (*Rana pipiens*) collected from a small swamp. The other two frogs were found to be negative for bladder flukes. One frog was examined fourteen days after the experimental feeding, and immature trematodes were found in the bladder. The other frog was examined thirty-one days after feeding the metacercariae, and sexually mature *Gorgodera amplicava* were recovered from the bladder. Several of these worms were producing eggs.

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JUNIOR ACADEMY OF SCIENCE

PROGRAM OF SIXTH ANNUAL MEETING

Saturday, November 7, 1936

9:30 a. m. Opening of display of exhibits.

10:30 a. m. Business meeting.
"History and purpose of the Junior Academy of Science" M. M. Williams, Bloomington.
Election of officers.
Discussion of various items of business.

12:00 m. Recess.

1:00 p. m. "Science and education in foreign schools" Dean Lester Smith, Indiana University.

1:45 p. m. Short talks by members of the Junior Academy.
"The preparation of skeletal materials" Melvin Fields, Jr., Muncie.
"Airline maintenance" Frank Gear, Muncie.
"Common and precious stones" Anna Thomas, Bloomington.
"Guinea pigs" Sidney Robinson, Bloomington.

2:45 p. m. Remarks by Dean H. E. Enders, Sponsor of the Junior Academy.

Minutes of Business Meeting

The Indiana Junior Acedamy of Science held its sixth annual meeting at Central Normal College, Danville, November 7, 1936. Merrill Eaton, of Bloomington, presided. Eighteen clubs responded to the roll call.

Dean Enders, sponsor of the Junior Academy, displayed a large map of Indiana showing the growth of the Junior Academy. He reported that ten new clubs had been admitted to affiliation during the year. The clubs and their sponsors were commended for their interest and for the excellent attendance at the meeting.

M. M. Williams, sponsor of the Bloomington club, spoke of the history and purpose of the Junior Academy and outlined the progress of education in scientific subjects in the schools.

The officers elected to serve in 1937 are as follows: President, George Hoffer, West Lafayette; Vice-President, David Williams, Valparaiso; Secretary, Barbara Badger, Shortridge High School; and Treasurer, Mary Tudor, Marion. Miss Anna Inskeep, West Lafayette, was elected to serve on the Advisory Council, taking the place of Emmett Stout, of Crawfordsville, whose five-year term had ended.

Dean Smith, of Indiana University, who was to have given the principal address of the afternoon, was unable to be present.

In the afternoon, Dr. Enders reported that the Indiana Junior Academy ranks second to the Illinois Junior Academy in membership and outstanding work. He commented favorably on the exhibits and suggested that each club make an effort to be represented at the meeting of the American Association for the Advancement of Science, to be held at Indianapolis in December, 1937.

A number of projects were reported, and many of the displays were explained.

About 150 persons attended the meeting.

Ruth M. Heitz, Secretary.

Exhibits

Sciemus Club, Valparaiso: Audio-amplifier and stethoscope, Morris Packman; Gyro-stabilizer, Eric Book; Ohm-meter, Harry Blocker; Ultraviolet ray lamp, David Williams; Electro-magnetic repulsion apparatus, Ralph Williams; Electric buzz-board, Robert Weiss; Device demonstrating the transfer of energy of two moving objects, Billy Savery.

General Science Club, Bloomington: Common and precious stones, Anna Thomas; Airplanes, Burton Clay and Ed Weimer; Common and rare snails, Leon Smith; Guinea pigs and Mendel's Law, Sidney Robinson; Common and foreign woods, Ann Pearson; Butterflies, Dick Adams.

Chemistry Club, Shortridge High School: Cosmetics used by the Egyptians, the American Indians, and by modern woman.

Science Club, Blaine Jr. High School, Muncie; Skulls and complete skeletons of numerous mammals.

Junior Academy of Science Club, Lew Wallace High School, Gary: Collections of plants and insects.

Science Club, West Lafayette: A century of progress in locomotive models, Radios; Steam engine, pelton wheel, electric motor; Mounted animals; Collection of moths and butterflies; Exhibit of corn products; Some things that have "made" the news columns: black widow spider, chinch bugs, praying mantis, witch hazel.

MEETINGS OF RELATED GROUPS

For the past several years those interested in entomology and in systematic botany have held informal conferences in connection with the regular fall meetings of the Academy. This custom was continued in 1936, both groups meeting on Saturday morning, November 7. Brief reports of the two meetings are given below.

Entomologists.—The meeting was called to order by Howard O. Deay, chairman. Among those present were: Dorothy Griffith, Dorothy Sparrow, and H. G. Nester, Butler University; C. C. Alexander, J. J. Davis, H. O. Deay, G. E. Gould, G. E. Lehker, G. E. Marshall, and B. E. Montgomery, Purdue University; H. K. Rippey, State Entomologist's Office; R. R. Heaton, the Terminex Company of Indiana; John M. Amos, Crop Protection Institute, Orleans, Indiana; J. T. Carter, Orleans; Robert Cooper, Ball State Teachers' College; and L. I. Musgrave, Martinsville.

The following program was presented:

1. Entomological work of the Academy Biological Survey Committee ..... B. E. Montgomery.
2. Biology and control of the Codling Moth ..... G. E. Marshall.
3. Entomological teaching and research in Indiana colleges and universities ..... H. G. Nester.
4. The present status of the Dutch elm disease, the European corn borer, and the Japanese beetle in Indiana ..... H. K. Rippey.
5. Extension methods in entomology ..... G. E. Lehker.

Following this program, others in attendance made brief reports of their work. H. G. Nester was elected chairman of the meeting to be held in 1937.

Plant Taxonomists.—The meeting was called to order by Theodore Just, chairman. Various phases of systematic botany, particularly as applied to immediate problems, were discussed by: C. C. Deam, Scott McCoy, Ray C. Friesner, Ralph M. Kriebel, Paul Weatherwax, Marcus W. Lyon, Jr., J. E. Potzger, and others. Theodore Just gave a summary of some recent European taxonomic literature.

By vote of the group, Theodore Just was continued as chairman for the coming year. Tentative plans were made for summer meeting of taxonomists to be held late in July.

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Butchart, Dr. John H., 4333 Cornelius St., Indianapolis
*Butler, Amos W., 52 Downey Ave., Indianapolis
Bybee, Halbert P., 210 South Madison St., San Angelo, Texas
Byers, Mark A., R. R. 3, Vincennes
Byrum, Irvin R., Modoc
*Cain, Dr. Stanley A., University of Tennessee, Knoxville, Tennessee
Caldwell, William I., Purdue University, West Lafayette
Call, Dr. Herbert F., 817 Hume Mansur Bldg., Indianapolis
Campbell, Guy, Lexington, Kentucky
Campbell, Marion S., 29 N. Hawthorne Lane, Indianapolis
Campbell, Miss Mildred F., 29 N. Hawthorne Lane, Indianapolis
Cannon, Rev. Dominic J., University of Notre Dame, Notre Dame
Carman, Prof. J. Ernest, 277 Fourteenth Ave., Columbus, Ohio
Carmella, Sister, Providence Convent, St. Mary of the Woods
Carmichael, Dr. A. M., 1925 W. Jackson St., Muncie
Carr, Arthur B., 1927 North New Jersey St., Indianapolis
*Carr, Dr. Ralph H., 27 N. Salisbury St., West Lafayette
Carroll, Miss Dorothy M., 555 West South St., Galesburg, Illinois
Carter, J. Cedric, University of Illinois, Urbana, Illinois
Carter, Edgar B., c/o Abbott Laboratories, North Chicago, Illinois
Cartwright, William B., 272 Federal Bldg., Sacramento, California
Cassady, Emil V., 3048 North Delaware St., Indianapolis
Caylor, Dr. Harold D., 303 South Main St., Bluffton

*Fellows

Child, Alfred T., Rose Polytechnic Institute, Terre Haute
Childs, Mrs. Laura G., 921 Atwater Ave., Bloomington
Childs, Lewis, West Baden
*Christy, Prof O. B., Ball State Teachers College, Muncie
Church, Josiah M., 4209 Virginia Ave., Louisville, Kentucky
Clark, Dr. Jediah H., 128 East Fourth St., Connersville
Clarke, Herbert M., Bacone College, Bacone, Oklahoma
*Clowes, G. H. A., c/o Eli Lilly and Co., Indianapolis
Coffing, Miss Charlene, 3332 Graceland Ave., Indianapolis
*Cogshall, Prof. Wilbur A., 423 South Fess Ave., Bloomington
Coleman, Dr. Christopher B., 4314 Central Ave., Indianapolis
Collings, W. Doyne, Box 175, Bainbridge
Collins, Dr. George, University of Notre Dame, Notre Dame
Conklin, Dr. Edmund S., Indiana University, Bloomington
Conn, Kenneth E., 703 South Washington St., Bloomington
Cook, James E., 2335 East Garfield Drive, Indianapolis
Cook, Rolla V., R. R. 5, Elwood
Cooper, Delmer C., University of Wisconsin, Madisen, Wisconsin
Cooper, Robert, 235 N. Washington St., Knightstown
Cooprider, J. L., Central High School, Evansville
Cope, Prof. Alfred B., Evansville College, Evansville
Copp, Paul T., 432 Jefferson St., Gary
*Corley, Dr. Ralph C., Purdue University, West Lafayette
Cortez, Samuel H., 1128 22d St., Ogden, Utah
Coryell, H. N., Columbia University, New York, New York
*Coulter, Dr. Stanley, c/o Eli Lilly and Co., Indianapolis
Cover, H. S., Chippewa Knoll, South Bend
Cowgill, Prof. Allen P., 2120 Crescent Ave., Fort Wayne
*Cowles, Prof. Henry C., University of Chicago, Chicago, Illinois
Cox, Prof. Alvalon C., 2948 Indianapolis Ave., Indianapolis
Cox, C. F., 528 North Oxford St., Indianapolis
Cox, Ronald C., 545 North Sunnyside Ave., South Bend
Cox, Samuel V., 1108 N. College Ave., Apartment 28, Indianapolis
Crandell, Jesse, Mar Main Arms Apt., South Bend
Crites, Jr., James E., Bloomington
Cromer, Prof. S. S., 915 Fifth St., West Lafayette
Crooks, Prof. Donald M., Ball State Teachers College, Muncie
Crow, Leonard R., 1220 North Seventh St., Terre Haute
*Cumings, Prof. Edgar R., 327 East Second St., Bloomington
Curtis, Miss Lila, 809 East Tenth St., Bloomington
Daggy, Tom, 215 North Ninth St., Richmond
Danglade, Jr., John A., R. R. 4, Vevay
Darragh, Miss Margaret L., 209 East Main St., Delphi
Davis, Miss Hazel J., 110 N. Fruitridge Ave., Terre Haute
*Davis, Dr. J. J., Purdue University, West Lafayette
Davis, R. C., Indiana University, Bloomington
Dawson, Ray F., R. R. 4, Tiffin, Ohio
*Deam, Charles C., Bluffton
Deay, Howard O., 912 Robinson St., Lafayette

*Fellows

*Degering, Dr. Edward F., Purdue University, West Lafayette
DeKay, Dr. H. George, Purdue University, West Lafayette
Demaree, Delzie, A. and M. College, Monticello, Arkansas
*Deppe, Prof. C. A., Franklin College, Franklin
Deppe, Charles F., 300 North Yandes St., Franklin
Deputy, Rolland, 85 Henry St., Franklin
Deupree, Dr. John F., Xavier University, Cincinnati, Ohio
Deuth, Martin J., 234 Natural History Bldg., University of Illinois, Urbana, Illinois
DeVries, Dr. Thomas, Purdue University, West Lafayette
Dickens, Albert E., Room 305, Statehouse, Indianapolis
Dickens, Prof. Karl L., L. S. U. Medical Center, New Orleans, Louisiana
Dickerson, L. L., Indianapolis Public Library, Indianapolis
Dietrich, Miss Barbara K., Borden
Dietz, Emil, 3225 Boulevard Place, Indianapolis
*Dietz, Dr. Harry F., 652 Bever St., Wooster, Ohio
Diltz, Charles D., 3121 Fairfield Ave., Fort Wayne
Doak, Kenneth D., Botanical Laboratory, University of Pennsylvania, Philadelphia, Pennsylvania
Doan, Dr. Martha, Iowa Wesleyan College, Mount Pleasant, Iowa
*Donaghy, Fred, Box 12, Terre Haute
Dotterer, Prof. John E., 404 Miami St., North Manchester
Douglass, Benjamin W., Trevlac
Downhour, Elizabeth, 725 N. Pennsylvania St., Indianapolis
Doyle, Dr. John J., Saint Mary of the Woods
Draper, Miss Olive May, Upland
Drybread, Miss Martha Ann, 301 E. Jefferson St., Franklin
Duncan, Wilbur H., R. R. 3, Bloomington
*Dunham, Prof. David H., 230 Connolly St., West Lafayette
*Dutcher, Dr. John B., 1212 Atwater Ave., Bloomington
Eagleson, Halson V., 304 East Tenth St., Bloomington
Eaton, Dr. Merrill T., Indiana University, Bloomington
Eckels, Lola M., 530 Putnam St., Fort Wayne
*Edington, Dr. Will E., DePauw University, Greencastle
Edmonson, Carl L., R. R. 2, Jasonville
*Edmondson, Dr. Clarence E., 618 Ballentine Road, Bloomington
Edwards, Prof. P. D., Ball State Teachers College, Muncie
Eggleston, Sister Mary F., St. Mary's College, Notre Dame
Eikenberry, Prof. A R., 608 Bond St., North Manchester
*Elliott, Dr. Edward C., Purdue University, West Lafayette
*Elliott, Prof. Frank R., Valparaiso University, Valparaiso
Elliott, Prof. S. E., 4624 Rookwood Ave., Indianapolis
*Enders, Dr. Howard E., 249 Littleton St., West Lafayette
Esarey, Ralph E., 924 Atwater, Bloomington
Esten, Mrs. Mabel M., 4112 Graceland Ave., Indianapolis
*Esten, Sidney R., 4112 Graceland Ave., Indianapolis
Etter, Austin, Grand Rapids Junior College, Grand Rapids, Michigan
Evans, Dr. Arthur T., Miama University, Oxford, Ohio
Evans, Dr. G. Harlowe, Taylor University, Upland

*Fellows

Evans, Richard I., University of Wisconsin, Madison, Wisconsin
Ewers, James E., 1220 North Ninth St., Terre Haute
Fay, Dr. Paul J., 13 Cole Apt., Greencastle
Ferguson, John E., Purdue University, West Lafayette
Ficht, George A., Box 73, Auburn
Fidlar, Marion M., Indiana University, Bloomington
Fidlar, Orville F., R. R. 1, Vincennes
Fine, Miss Mary Ellen, 107 South Grant Ave., Crawfordsville
Finger, Glenn C., 111 State Geological Survey, Ceramics Bldg., Urbana, Illinois
Fish, William E., 145 Andrew Place, West Lafayette
*Fisher, Martin L., Purdue University, West Lafayette
Fitch, Harry N., 404 Beechwood Ave., Muncie
Flemion, Miss Florence D., Boyce Thompson Institute, Yonkers, New York
Fletcher, Miss Hazel M., Modoc
Fletcher, Dr. Worth A., University of Wichita, Wichita, Kansas
Floe, Dr. Carl F., University of Notre Dame, Notre Dame
Flood, Sister M. Acquinas, Mary Manse College, 2413 Collingwood Ave., Toledo, Ohio
Florintine, Sister M., St. Mary's College, Notre Dame
*Foley, Arthur L., Indiana University, Bloomington
Foresman, George K., 808 South St., Lafayette
Forsyth, Owen, 2520 Cass St., Fort Wayne
Frandzel, Ben W., 1900 South Third St., Terre Haute
Freed, Richard G., Dept. of Geology, Indiana University, Bloomington
Frick, Charles H., Valparaiso University, Valparaiso
Friesner, Mrs. Gladys M., 3707 N. Gladstone Ave., Indianapolis
*Friesner, Dr. Ray C., Butler University, Indianapolis
*Froning, Prof. Henry B., 415 Pokagon St., South Bend
Frushour, J. H., Oldenburg
Fulford, Miss Margaret, University of Cincinnati, Cincinnati, Ohio
Fullenwider, Miss Eleanor J., 419 W. 49th, St., Indianapolis
Fulmer, Dr. Jarvis M., 612 Highwood Ave., Greencastle
Funk, Dr. Austin, 404 Spring St., Jeffersonville
*Galloway, Dr. Jesse J., Indiana University, Bloomington
*Gardner, Dr. Max W., University of California, Berkeley, California
Garner, Dr. Murvel R., Earlham College, Richmond
Garver, Frederick R., Fairland
Gassensmith, Rev. Frederick M., Notre Dame
Gatch, Dr. Willis D., 605 Hume-Mansur Bldg., Indianapolis
Gates, Miss Florence A., 3435 Detroit Ave., Toledo, Ohio
Geisler, Florence, 2267 N. Dearborn St., Indianapolis
Geisler, Walter C., 2267 N. Dearborn St., Indianapolis
*George, Roscoe H., 332 W. Stadium Ave., W. Lafayette
Germann, Dr. A. F. O., South Whitley
Gettelfinger, Wilfrid C., Ramsey
Giddings, Dr. Glenn W., DePauw University, Greencastle
Gierut, Rev. Joseph A., 124 Lyons Hall, Notre Dame

*Fellows

Gingery, Walter G., Washington High School, Indianapolis
*Giordano, Dr. Alfred S., 1222 25th St., South Bend
*Girton, Dr. Raymond E., 132 DeHart St., W. Lafayette
Glenn, Earl R., New Jersey State Teachers College, Montclair, New Jersey
Glenn, Dr. Oliver E., 127 McKinley Ave., Lansdowne, Pennsylvania
Goldman, John M., 204 Walnut St., Rockport
Goldsmith, Dr. William M., University of Wichita, Wichita, Kansas
Goshorn, Roland H., Ladoga
Gould, E. S., 3306 Indiana Ave., Fort Wayne
Gould, George E., Agricultural Exper. Station, W. Lafayette
Graam, Mrs. Dona G., Indiana State Normal School, Terre Haute
Graham, Frank V., Ball State Teachers College, Muncie
Grant, Major Chapman, 2970 Sixth Ave., San Diego, California
Grant, Mrs. Charlotte, L., 3302 Graceland Ave., Indianapolis
*Grave, Prof. Benjamin H., DePauw University, Greencastle
Gray, Miss Nina E., Illinois State Normal University, Normal, Illinois
Gray, William D., 214 Pearl St., Jeffersonville
Green, Darrell B., 5 Arden Place, Athens, Ohio
Greenawalt, Stewart, Madison, Pennsylvania
Greene, Frank C., Box 138, Rolla, Missouri
*Greene, Laurenz, 920 Stadium Ave., W. Lafayette
Gregory, Howard W., 416 Stadium Ave., W. Lafayette
Griffin, Miss Agatha, 1816 Commerce Ave., Indianapolis
Grosjean, Thomas H., 1312 South Center St., Terre Haute
Gross, Miss Catherine L., University of Wisconsin, Madison, Wisconsin
Guard, Arthur T., Purdue University, W. Lafayette
*Guernsey, E. Y., 1421 "O" St., Bedford
Gunder, Miss Olive L., 30 Drexel Ave., Indianapolis
Gutermuth, Clinton R., 3025 N. Meridian St., Indianapolis
Guthrie, Ned, Hanover College, Hanover
Haas, Dr. Arthur, University of Notre Dame, Notre Dame
*Haas, Dr. Flora A., A.S.T.C. Normal Station, Conway, Arkansas
Hafel, Clare P., 106 N. Hooker St., Caney, Kansas
Hall, Fred T., 1215 Danville Ave., Crawfordsville
Hall, Dr. O. F., 829 N. Sallisbury St., W. Lafayette
Hall, William C., 3305 South Seventh St., Terre Haute
Hammersley, William L., Jr., 51 East Walnut St., Frankfort
Hanna, Prof. U. S., 828 Atwater Ave., Bloomington
Harger, Earl L., Jr., 503 Granville Ave., Muncie
*Harger, Dr. Rolla N., 5015 Graceland Ave., Indianapolis
Hargitt, Dr. George, Duke University, Durham, North Carolina
Hargitt, Dr. Thomas F., Illinois Wesleyan University, Bloomington, Illinois
Hargrave Ellis, Washington High School, Indianapolis
Harmon, Daniel L., St., Mary of the Woods
Harmon, Dr. Jesse, 2329 West 18th St., Wilmington, Delaware
*Harmon, Dr. Paul M., 505 Ballantine Road, Bloomington
Harrar, Dr. Norman J., Franklin College, Franklin

*Fellows

Harrell, Marshall A., U. S. Geological Survey, Washington, D. C.
Harris, David V., U. S. Soil Conservation Service, Albuquerque, New Mexico
Harris, Howard, 340 W. Raymond St., Indianapolis
Hartman, Dr. Robert J., Indiana University, Bloomington
Hartsell, Dr. Stanley E., Purdue University, W. Lafayette
Harvin, Glenn B., Fayetteville, North Carolina
Hass, Dr. Henry B., Purdue University, W. Lafayette
Hassmer, Joseph, Lawrenceburg
Hatfield, Nicholas W., 3302 Fall Creek Blvd., Indianapolis
Hawkins, Stacy O., Agricultural Experiment Station, Gainesville, Georgia
Hawley, William, R. R. 1, Box 22, North Liberty
Haynes, James L., 17th St., Bloomington
Hazlett, Donald C., Russellville
Headlee, William H., Purdue University, W. Lafayette
Hebert, Dr. Peter E., University of Notre Dame, Notre Dame
Helman, Rev. Howard H., 604 East Ninth St., North Manchester
Henderson, Miss Ruth V., 3019 N. California Ave., Indianapolis
Hendricks, Jesse C., Box 82, Clemson, South Carolina
Hendricks, Thomas, 2518 Broadway, Indianapolis
Hennel, Dr. Cora B., 410 South Park Ave., Bloomington
Hennion, Dr. George F., University of Notre Dame, Notre Dame
Herr, Shirl, 700 S. Water St., Crawfordsville
Hertzler, Dr. Silas, 110 West Lafayette St., Goshen
*Hessler, Robert, 25 S. Bolton St., Indianapolis
Hickman, Dr. Cleveland P., 315 Greenwood Ave., Greencastle
Hiegel, Alfred J., Box 16, Notre Dame
*Hiestand, Dr. Wm. A., Purdue University, W. Lafayette
Hightower, Dr. P. R., 501 Buckingham Drive, Indianapolis
Hile, Dr. Ralph, University Museums. Ann Arbor, Michigan
Hill, Miss Marian J., 1030 Bradbury Ave., Indianapolis
Hills, Donald C., 718 West 31st St., Indianapolis
Hinman, Jack J., Jr., Box 363 University of Iowa, Iowa City, Iowa
Hitz, Benjamin D., 120 S. Alabama St., Indianapolis
*Hoffer, George N., 1127 N. Grant St., W. Lafayette
Hoffman, A. C., 5760 Lowell Ave., Indianapolis
Holderman, Miss Mary E., 511 S. Monticello, Winamac
*Hole, Allen D., 615 National Road West, Richmond
Holl, Dr. Carl W., North Manchester
Hooper, Miss Florence, Boyce Thompson Institute, Yonkers, New York
Horan, Frank W., 914 Diamond Ave., South Bend
Horton, George W., Crawfordsville
Hoskins, Dr. John H., University of Cincinnati, Cincinnati, Ohio
Houdek, Paul K., 207 N. Jefferson, St., Robinson, Illinois
Houk, Miss Willa, 317 N. Second St., Linborg, Kansas
*Howell, L. B. Wabash College, Crawfordsville
Howie, Hillis L., 4443 Guilford Ave., Indianapolis
*Howlett, Berton A., 2330 South Seventh St., Terre Haute

*Fellows

Huddle, John W., University of North Carolina, Chapel Hill, N. Carolina
*Hufferd, Ralph, DePauw University, Greencastle
*Hufford, Dr. Mason E., 514 Woodlawn, Bloomington
Hughes, William L., R. R. 3, Delaware, Ohio
Hull, Louie R., 314 N. Seminole Circle, Fort Wayne
*Hulpieu, Dr. H. R., 3720 N. Penn. St., No. 7, Indianapolis
Hunsaker, Miss Frances C., 509 S. Main St., Anna, Illinois
Hunt, Raymond S., 210 W. High St., Mt. Pleasant, Michigan
Hurlbut, Dr. Floy, 2108 W. Main St., Muncie
Hurst, Lawrence, 320 N. Talley Ave., Muncie
Hurwitz, Joseph, 417 Waldron St., W. Lafayette
Hutchinson, Emory, Norman Station
Hyatt, Joseph L., Hanover College, Hanover
Hydle, Lars L., Ball State Teachers College, Muncie
Inskeep, Miss Anna M., Monticello
Irons, Dr. Vernal, State Department of Health, Austin, Texas
Irving, Thomas P., University of Notre Dame, Notre Dame
Isselhardt, Ralph, Kappa Delta Pi House, Franklin
Jack, Homer A., 290 Crosman Terrace, Rochester, New York
James, Dr. Hubert M., Purdue University, W. Lafayette
Jamieson, W. A., c/o Eli Lilly and Co., Indianapolis
Jefferson, Mrs. Louise P., Springport
Jennings, Robert K., Cary Hall East, W. Lafayette
Johnson, Benjamin, R. R. 5, Petersburg
Johnson, Mrs. J. H., 1702 N. Alabama St., No. 14, Indianapolis
Johnson, Willis H., Wabash College, Crawfordsville
Johnston, T. R., Purdue University, W. Lafayette
Jones, David T., 818 E. Fifth St., Vinton, Iowa
Jones, Miss Martha J., 1400 S. 11½ St., Terre Haute
*Jordan, Charles B., Purdue University, W. Lafayette
Jordan, Miss Ruth, 230 Harrison St., W. Lafayette
Joy, Mrs. Arthur H., Michigan State Sanatorium, Howell, Michigan
Julian, Dr. Percy L., 715 Crown St., Greencastle
Junker, Paul E., 4220 Hale Ave., Louisville, Kentucky
*Just, Dr. Theodore, University of Notre Dame, Notre Dame
*Kaczmarck, Regidium M., University of Notre Dame, Notre Dame
Kanning, Dr. Eugene W., Indiana University, Bloomington
Kaufman, Dr. Fred, Valparaiso University, Valparaiso
Kells, Homer, 2202 South Washington St., Marion
Kemper, Miss Mary E., Grant Hospital of Chicago, Chicago, Illinois
Kendall, William R., 4 Garfield Ave., Valparaiso
Kennedy, Dr. Clarence H., Ohio State University, Columbus, Ohio
Kennedy, Glenn D., 227 DeHart St., West Lafayette
Kenoyer, E. Fay, 3216 Ralston Ave., Indianapolis
Kensler, George T., 309 S. Sixth St., Vincennes
*Kern, Frank D., State College, Pennsylvania
Killian, Donald B., R. R. 7, Willowdale, North Canton, Ohio
Kimmell, Miss Anna May, Kimmell

*Fellows

King, Samuel M., Taylor University, Upland
King, Terry N., 444 Arcadia Court, Fort Wayne
*Kinsey, Dr. Alfred C., 615 S. Park Ave., Bloomington
Kintner, Burton E., North Manchester
*Kintner, Edward, 1004 East St., North Manchester
Kintner, Elgin P., North Manchester
Kintner, Kenneth E., 1004 East St., North Manchester
Kintner, M. Quentin, 1004 East St., North Manchester
Kline, Rev. James E., University of Notre Dame, Notre Dame
Klopp, G. Donald, 1075 E. Hanna Ave., Indianapolis
Knecht, Christian, 207 N. Dunn St., Bloomington
Kney, Miss Charlotte C., Waldron
*Knipmeyer, Clarence C., 2611 N. Eighth St., Terre Haute
Knipp, Dr. Julian K., 414 Forrest St., Lafayette
Knott, Miss Gladys E., 821 E. Elm St., New Albany
*Koch, Dr. Edward W., 24 High St., Buffalo, New York
Koch, Miss Norma, 2222 S. Delaware St., Indianapolis
*Kohl, Edwin J., 700 N. Main St., West Lafayette
*Kraybill, Dr. Henry R., 302 Waldron St., W. Lafayette
Kriebel, Ralph M., 1111 North St., Bedford
Kroeger, Wm. J., 417 N. Williams St., South Bend
Krom, A. B., 288 N. Miami St., Wabash
Kuebler, John R., 304 Burgess Ave., Indianapolis
Kunkel, Kenneth M., 3608 N. Meridian St., Indianapolis
Kurtz, Gaylord S., 2522 Hubertus St., Fort Wayne
Lahr, J. P., 4921 Broadway, Indianapolis
LaHue, Delmon W., 705 Meridian St., W. Lafayette
Lamey, Carl A., 2258 Summit St., Columbus, Ohio
Lancaster, Robert F., Calhoun St., South Whitley
deLandero, Pedro A., 1031 N. Niles Ave., South Bend
Landon, Hugh McK., Fletcher Trust Co., Indianapolis
Lang, Miss Maud O., R. R. 2, Box 37, Rockport
Lanham, Miss Bess, Newport
Lanterman, W. F., 309 HiLusi St., Mount Prospect, Illinois
Lapenta, Dr. Vincent A., 711 Indiana Pythian Bldg., Indianapolis
*Lark-Horovitz, Dr. Karl, Purdue University, W. Lafayette
Leach, William J., Temple University, Philadelphia, Pennsylvania
*Lee, Charles O., 600 Robinson Ave., West Lafayette
Lee, Fitzhugh, W. South St., Mooresville
Lefforge, Ernest E., Oaklandon
Lefler, Glenn Q., Warren
Lefler, Ralph W., 201 E. 11 St., Peru
Lehker, Glen E., Agricultural Experiment Station, W. Lafayette
Lehman, Dr. M. C., 1425 S. Eighth St., Goshen
Lemon, Miss Lola May, Larwill
*Lieber, Col. Richard, 3119 N. Meridian St., Indianapolis
Lillick, Miss Lois, 6634 Iris Ave., Cincinnati, Ohio
Lilly, Eli, Eli Lilly and Co., Indianapolis
Lindberg, Dr. Carl F., Valparaiso University, Valparaiso

*Fellows

Linville, Ralph B., Baxter Hall, Illinois College, Jacksonville, Illinois
Liston, Jesse G., R. R. 2, Jasonville
Lloyd, Miss Gladys, 749 Johnson Ave., Franklin
Lloyd, Mrs. W. H., 210 Garfield Ave., Valparaiso
Loew, Fred A., 916 Hime St., Huntington
*Logan, Wm. N., 924 Atwater Ave., Bloomington
Lott, A. V., Sellersburg
Loughridge, Gasper A., Goodland
Louraine, Frank E., 42 Independence Ave., Apt. 304, Washington, D. C.
Louttit, Dr. Chauncey M., R. R. 3, Bloomington
Love, Miss Louise, 600 South 19th St., Terre Haute
Lowe, Miss Grace D., 224 Gilbert Ave., Terre Haute
Lucey, Sister Mary Ruth, St. Mary of the Woods
Ludwig, Dr. C. A., Bureau of Chemistry and Soils, Dept. of Agriculture, Washington, D. C.
*Ludy, Llewellyn V., Purdue University, West Lafayette
Luttman, Joseph F., University of Notre Dame, Notre Dame
*Lyon, Dr. Marcus W., 214 LaPorte Ave., South Bend
*Lyons, Dr. Robert E., 630 East Third St., Bloomington
McAtee, Dr. W. L., 200 Cedar St., Cherrydale, Virginia
McAvoy, Miss Blanche, Illinois State Normal University, Normal, Illinois
McCohaha, Miss Marjorie, State University of Iowa, Iowa City, Iowa
McCormick, Clyde T., 1422 Monon Drive, Bloomington
*McCormick, Robert N., 508 S. Talley Ave., Muncie
McCoy, Ralph W., Williams
McCoy, Scott, 3444 N. Illinois St., Indianapolis
McKee, Lefler, 509 A St., N. E., Linton
McKee, Miss Madge, Goodland
McKee, Roy, 419 East South Dakota St., Gas City
McKenney, Miss Bernice, R. R. 3, Shelbyville
McKeon, Rev. Frederick T., University of Notre Dame, Notre Dame
Maass, George H., 2522 South Delaware St., Indianapolis
*MacGillivray, Dr. J. H., Truck Crops Division, Davis, California
*Mackell, James F., R. R. 1, Terre Haute
Maehling, J. J., 1357 Third Ave., Terre Haute
*Mahin, Dr. Edward G., University of Notre Dame, Notre Dame
*Mains, Dr. E. B., University of Michigan, Ann Arbor, Michigan
Malek, George, 703 East Illinois Ave., Morris, Illinois
Malott, Burton J., Technical High School, Indianapolis
*Malott, Dr. Clyde A., 708 Woodlawn Ave., Bloomington
*Markle, M. S., Earlham College, Earlham
Marshall, G. E., Orleans
Martens, J. Louis, 515 South Woodlawn Ave., Bloomington
Martin, Don D., North Manchester
Martin, Ersie S., 134 North Drexel St., Indianapolis
Martin, Miss Lois F., Walton
Martin, R. Earl, Hanover College, Hanover
Martin, Mrs. Viva D., 134 Drexel St., Indianapolis

*Fellows

Martin, Walter E., 453 Littleton St., West Lafayette
Marting, Dorsey P., Weather Bureau Office, Box 1210, Roseburg, Oregon
*Mason, Thomas E., Purdue University, West Lafayette
Mathers, Dr. Frank C., 503 S. Ballentine Road, Bloomington
Mathias, Harry R., 123 East Evers Ave., Bowling Green, Ohio
Matthews, Prof. Mary L., 629 Waldron St., West Lafayette
Means, Dr. Karl S., Butler University, Indianapolis
Meikle, G. Stanley, 303 Russell St., West Lafayette
*Mellon, Dr. Melvin G., 9 Russell St., West Lafayette
Meyer, Miss Adelphia, Ball State Teachers College, Muncie
Meyer, Dr. A. H., Valparaiso University, Valparaiso
Michael, Lyle J., Indiana Central College, Indianapolis
Michaud, Howard H., 2616 West Drive, Fort Wayne
*Middleton, Dr. Arthur R., 705 Russell St., West Lafayette
Middleton, Robert E., Dominion Experiment Station, Kapuskasing, Ontario, Canada
Middleton, Dr. Warren C., 401 East Seminary, Greencastle
Miles, Everett E., 4126 Arlington St., Fort Wayne
Miller, Mrs. Edwin L., Louisiana State University, Baton Rouge, Louisiana
Miller, Fred A., R. R. 2, Greenfield
Miller, Dr. Glen R., 1419 South Ninth St., Goshen
Miller, Harold V., 407 Armstrong Bldg., Knoxville, Tennessee
Miller, John T., U. S. Dept. of Agriculture. Bureau of Chemistry and Soils, Washington, D. C.
Miller, Dr. Sayers J., 10 North 27th St., Lafayette
Miltner, Dr. Charles, University of Notre Dame, Notre Dame
Miner, Dewey H., 440 West 35th St., Kansas City, Missouri
Miner, Wallace B., Mishawaka High School, Mishawaka
Minnesota Academy of Science, University of Minnesota Library, Minneapolis, Minnesota
Mitchell, Miss Elta A., R. R. 3, Franklin
Mitten, Arthur G., R. R. 1, Goodland
*Montgomery, Elwood, Purdue University, West Lafayette
Moore, John A., 114 South Ritter St., Indianapolis
Moore, John I., 233 West Twohig, San Angelo, Texas
Morgan, Dr. Lenord C., 5440 Kenwood Ave., Indianapolis
*Morgan, Dr. W. P., 4115 Otterbein Ave., Indianapolis
Morris, Dr. Charles S., 601 N. Wayne St., North Manchester
*Morrison, Edwin, Michigan Agricultural College, East Lansing, Michigan
Morrison, Harold. 1725 Gamout St., N. W., Washington, D. C.
*Mottier, David M., 215 Forest Place, Bloomington
Mozingo, Ralph V., University of Wisconsin, Madison, Wisconsin
Mullen, Dr. Lowell, Lakeside, Washington
*Mullendore, Miss Naomi, Franklin
*Munro, George W., Purdue University, West Lafayette
Murphy, Miss Rosemary A., Wellesley College, Wellesley, Massachusetts
Murray, Dr. Leo T., Director of Museum, Baylor University, Waco, Texas

*Fellows

Murray, Merritt J., Station for Exp. Evol., Cold Spring Harbor, Long Island, New York
*Myers, Dr. B. D., 424 North Walnut St., Bloomington
Myers, Miss Elizabeth N., 1414 Ewing St., Indianapolis
Myers, George S., Natural History Museum, Stanford University, Stanford, California
Myers, Raymond J., 29 Hamilton St., Hamilton, New York
Neff, Mrs. Ivy J., R. R. 4, Delphi
Neher, O. W., 608 East Miami St., North Manchester
Nelson, J. C., R. R. 2, Box 598-y, Indianapolis
Nelson, Dr. Ralph E., 232 Littleton St., West Lafayette
*Nester, Henry G., 2832 North Capitol, Indianapolis
*Newton, Dr. Roy F., 1132 Ravinia Road, West Lafayette
Niles, Edward H., 4450 Guilford Ave., Indianapolis
Nixon, Victor E., R. R. 2, Oakland City
Noble, Jr., Dr. Thomas B., R. R. 17, Box 187, Indianapolis
Noble, Willis B., Box 495, West Lafayette
Noland, Dr. Stephen C., The Indianapolis News, Indianapolis
Norcross, Gerald W., 718 Weghorst St., Indianapolis
Northwestern University, Evanston, Illinois
Noss, Theodore K., Purdue University, West Lafayette
Noyes, Dr. Bessie, 1607 North Seventh St., Terre Haute
Noyes, Harry A., Applied Sugar Laboratories, 111 Wall St., New York City
O'Brien, Cornelius, 455 Ridge Ave., Lawrenceburg
O'Hara, Rev. Francis J., St. Edward's University, Austin, Texas
O'Neal, Dr. Claude E., Ohio Wesleyan University, Delaware, Ohio
O'Shea, Miss Harriet, Purdue University, West Lafayette
*Oberholser, Harry C., 2805 Eighteenth St., N. W., Washington, D. C.
Offutt, Andrew C., 1205 Audubon Road, Newcastle
Oswald, Jack W., 424 South Sixth Ave., LaGrange, Illinois
Otten, Dr. Ralph E., Philadelphia General Hospital, Philadelphia, Pennsylvania
Oury, Clarence M., 374 East Main St., Peru
*Packard, C. M., Box 495, Lafayette
*Painter, Henry R., Box 495, Lafayette
*Palmer, C. M., Butler University, Indianapolis
Parker, Miss Dorothy, Bargersville
Parker, William A., Monroe City
Pauley, Claude O., 255 Plum St., Valparaiso
Payne, Clark B., National Press Bldg., Washington, D. C.
Payne, Elmer C., 293 Elmhurst Ave., Elmhurst, Illinois
*Payne, Fernandus, 620 Ballantine Road, Bloomington
Pearce, Dennis W., Purdue University, West Lafayette
*Pearson, Dr. Nathan E., Butler University, Indianapolis
Penrod, Miss Blanche, 1839 Thompson St., Indianapolis
Perkins, III, S. E., 709 Inland Bldg., Indianapolis
Perkins, Wendell L., Indiana State Teachers College, Terre Haute
Peters, Gustavus A., Indiana University, School of Medicine, Indianapolis

*Fellows

Peterson, Lawrence H., 3516 Mersington St., Kansas City, Missouri
Petry, Dr. E. J., 129 36th St., N-E., Cedar Rapids, Iowa
Phillips, Rees L., 133 Pierce St., West Lafayette
Piatt, Jean, 344 Northern Ave., Indianapolis
Pickett, Fermen L., Station 178, Pullman, Washington
Pierce, Miss Marjorie E., Medora, North Dakota
Piersma, Henry D., Purdue University, West Lafayette
Pinkerton, Earl, Box 447, Walters, Oklahoma
Pitkin, Dr. Edward M., Martinsville Sanatorium, Martinsville
Pittenger, John S., 1117 May St., Hammond
Pittenger, Lemuel A., 602 North Calvert Ave., Muncie
Plasterer, Eiffel G., 213 Wright St., Huntington
Pontius, Mrs. Minerva B., 330 East Ann St., Ann Arbor, Michigan
*Poorman, Alfred P., 329 Russell St., West Lafayette
*Porter, Charley L., 924 North Main St., West Lafayette
Porter, John N., 924 North Main St., West Lafayette
Post, Francis A., 920 North Center St., Terre Haute
Post, Mrs. Ida M., 920 North Center St., Terre Haute
Potter, Dr. Andrey A., 1012 Stadium Ave., West Lafayette
*Potzger, Dr. John E., Butler University, Indianapolis
Powell, Dr. G. Maxwell, 605 J.M.S. Bldg., South Bend
Powell, Dr. Horace M., 3947 N. Illinois St., Indianapolis
Powers, Roscoe, 836 Villa Ave., Indianapolis
Price, George W., 41 N. Webster Ave., Indianapolis
Price, James F., Butler University, Indianapolis
Price, J. Waide, 128 Louis Ave., Cincinnati, Ohio
Quick, Carl J., 1239 East State St., Fort Wayne
Quinn, Robert B., R. R. 2, Valparaiso
Rabb, Albert L., 1351 Consolidated Bldg., Indianapolis
Ragains, Robert A., 4120 Otterbein Ave., Indianapolis
Railsback, O. L., Teachers College, Charleston, Illinois
Ramsey, Hugh S., 612 University St., Bloomington
*Ramsey, Rolla R., 615 East Third St., Bloomington
Ransom, Clemie E., 2202 N. Capitol Ave., Indianapolis
Rasmussen, Rasmus G., Rasmussen Court, New Albany
Rauth, Adolph W., Consumers Power Bldg., Jackson, Michigan
Rawles, William P., 415 North Park Ave., Bloomington
Reavis, Dr. Tolbert F., 3962 Ruckle St., Indianapolis
Rechenberg, Miss Elizabeth A., 805 Brown St., Valparaiso
Records, Ralph L., Box 277, Edinburg
Reed, Dr. Fredda D., Mount Holyoke College, S. Hadley, Massachusetts
*Reed, Harry J., Agricultural Experiment Station, West Lafayette
Rees, Myron L., 37 East Maple Road, Indianapolis
Reeves, John L., 214 South St., West Lafayette
Remmers, Dr. Herman H., Purdue University, West Lafayette
*Rettger, Dr. Louis J., Indiana State Teachers College, Terre Haute
Reynolds, Albert E., 812 S. College Ave., Greencastle
Rich, Ronald E., 402 East Howard St., South Bend

*Fellows

Richter, Arthur, Flora
Richter, Kenneth M., 33 N. Wallace St., Indianapolis
Riebsomer, Dr. J. L., 210 South Indiana St., Greencastle
Riecken, William E., Millsaps College, Jackson, Mississippi
Rifenburg, S. A., 246 Marstellar St., West Lafayette
Rippey, H. K., State Library Bldg., Indianapolis
Ritchie, Earland, Yorktown
Robbins, Charles K., 418 Vine St., West Lafayette
Robertson, Frank S., Box 7, Ewing
Roehm, John C., Box 2652, Juneau, Alaska
Roff, Dr. Merrill F., Indiana University, Bloomington
Rogers, Roy, North Madison
Romberger, Jr., Dr. Floyd, Methodist Hospital, Indianapolis
Rose, James B., 447 Bosart Ave., Indianapolis
Rose, John K., Rosenwald Hall, University of Chicago, Chicago, Illinois
Rosenbaum, John R., Wanatah
Ross, Jr., Oran E., 200 East South St., Winchester
*Rothrock, David A., 1000 Atwater Ave., Bloomington
Rothrock, Jr., David A., 1000 Atwater Ave., Bloomington
Rothrock, Henry S., DuPont Research Laboratories, Wilmington, Delaware
Routien, John B., Montezuma
Russell, Merwyn A., 224 North Harrison St., Rushville
Ryan, Everett R., 55 South Ninth Ave., Beech Grove
Ryder, Raymond R., 703 Hayes St., West Lafayette
*Samson, R. W., 115 Connelly St., West Lafayette
Scally, Miss Lena, Box 227, Elkhart
Scarf, Dr. Robert C., Ball State Teachers College, Muncie
Schilke, Ugo M., University of Notre Dame, Notre Dame
Schilling, Dr. Clarence G., Purdue University, West Lafayette
Schlender, Miss Emma, 1919 Ruckle St., Indianapolis
Schoff, Stuart L., DePauw University, Greencastle
*Schockel, Bernard H., Indiana State Normal School, Terre Haute
Schweiger, Leonard B., 212½ S. Grant St., West Lafayette
Scofield, Robert, Crisman
Scott, Miss Beth, 918 North Riley Ave., Indianapolis
Scott, Dr. J. Paul, 811 South Grant Ave., Crawfordsville
*Scott, Will, Indiana University, Bloomington
Sears, Miss Velma L., 1616 Fifteenth St., Bedford
Seaton, Jerome P., 313 Russell St., West Lafayette
Setzler, Frank M., U. S. National Museum, Washington, D. C.
Seybert, John E., 4842 Kenwood Ave., Indianapolis
Sheean, J. Lyman, 45 Fifth St., Cloquet, Minnesota
Shelley, Robert L., 503 Wabash Ave., Bluffton
Shideler, Dr. William H., 110 S. Campus Ave., Oxford, Ohio
Shock, Joseph H., 630 N. Seventh St., Lafayette
Shock, N. W., University of California, Berkeley, California
Shoemaker, Hurst H., University of Chicago, Chicago, Illinois
Shoemaker, Vaughn, R. R. 2, Madison

*Fellows

Shonle, Horace A., c/o Eli Lilly and Co., Indianapolis
Showalter, Ralph W., c/o Eli Lilly and Co., Indianapolis
Shriner, Dr. Walter O., 2525 N. Ninth St., Terre Haute
Shrock, Robert R., University of Wisconsin, Madison, Wisconsin
Shultz, Irvin T., 4246 Fairview Terrace, Indianapolis
Shuttleworth, Floyd S., Alpine
Silvey, Oscar W., College Station, Texas
Simmons, V. M., 3608 N. Meridian St., Indianapolis
Simpson, Robert C., Box 88, R. R. 2, Vincennes
Sisson, Robert, 40 South Mulberry St., Martinsville
Skinner Charles H., Marquette University, Milwaukee, Wisconsin
Skinner, Olind, R. R. 2, Crown Point
Slusser, Mack W., Box 164, Lebanon
Smith, Arthur L., Central High School, South Bend
Smith, Benjamin H., Indiana State Teachers College, Terre Haute
Smith, Dr. Charles P., 976 Riverside Ave., San Jose, California
*Smith, Ernest R., 628 East Walnut St., Greencastle
*Smith, Dr. Orrin H., 430 Anderson St., Greencastle
Smith, Pressnall, 2007 Gulford St., Huntington
Smithberger, Andrew T., 1516 Hildreth St., South Bend
Sousley, Dr. Clarence P., Rose Polytechnic Institute, Terre Haute
South Carolina Academy of Science, University of South Carolina, Columbia, South Carolina
Sowa, Frank J., 3010 Green St., South Bend
Spahr, Raymond J., 5657 Miriam Road, Frankford, Philadelphia, Pa.
Sperry, Dr. Theodore M., University Park, SP 14, Madison, Wisconsin
*Stair, Edward C., Purdue University, West Lafayette
Stanley, Miss Ina, 417 East 46th St., Indianapolis
Stanley, Oran B., Colgate University, Hamilton, New York
Steen, Edwin B., 118 East Oak St., West Lafayette
Steinbach, Leslie I., Central Normal College, Danville
Steward, Mrs. Beatrice E., Norman Court Apts., Dayton, Ohio
Stillson, Miss Blanche, 4245 N. Meridian St., Indianapolis
Stock, Orion L., Rose Polytechnic Institute, Terre Haute
*Stockdale, Paris, Ohio State University, Columbus, Ohio
Stoelting, Miss Dorothy, 318 N. Arsenal Ave., Indianapolis
Stone, Ralph B., 615 Russell St., West Lafayette
Stork, Miss Mary L., 310 Washington Ave., Evansville
Stout, Emmett C., 417 School St., Crawfordsville
Stout, Wilbur, 154 Erie Road, Columbus, Ohio
Strickler, Dr. Alvin, Evansville College, Evansville
Stults, Arline, R. R. 2, Box 232, Huntington
Sullivan, Russell, 1431 N. Meridian St., Indianapolis
Sulzer, Elmer G., University of Kentucky, Lexington, Kentucky
Swanson, Miss Caroline, 7816 Gregier Ave., Chicago, Illinois
*Switzer, J. Elmer, 523 South Park Ave., Bloomington
Swope, Ammon, 906 Northwestern Ave., West Lafayette
Taggard, Matt F., 1528 Lincoln Way East, South Bend
Tallman, Arthur W., Johnston, Ohio

*Fellows

Tasker, Roy C., Bucknell University, Wilkes-Barre, Pennsylvania
Taylor, George O., 1832 South 58th Ave., Cicero, Illinois
Taylor, Merrel A., 4143 Boulevard Place, Indianapolis
Teder, John H., Jasper
Teel, William R., 5580 Washington Blvd., Indianapolis
Teeter, Russel V., 2537 N. Pennsylvania Ave., Indianapolis
Terre, Wilbert L., 2730 Chicago Road, Chicago Heights, Illinois
Test, Frederick H., Museum of Vertebrate Zoology, University of California, Berkeley, California
*Test, Dr. Louis A., 511 Russell St., West Lafayette
*Tetrault, Phillip A., Purdue University, West Lafayette
Tharp, William E., Bureau of Chemistry and Soils, U. S. Dept of Agriculture, Washington, D. C.
Thom, Miss Dorothy, 248 North Home Ave., Franklin
Thomas, Dr. Harry B., 610 N. Lincoln St., Bloomington
Thompson, Charles N., 3650 Washington Blvd., Indianapolis
Thompson, Clem O., University of Chicago, Chicago, Illinois
Thompson, Harold B., 404 Grace Ave., Crawfordsville
Thompson, Miss Vesta, 521 Oakdale Drive, Fort Wayne
Thompson, Wallon H., R. R. 3, Box 234, Madison
Thornbury, William D., Indiana University, Bloomington
Tinkle, Dr. William J., Taylor University, Upland
Torrey, Dr. Theodore W., Indiana University, Bloomington
Tranter, Frank, 448 East Madison St., Franklin
Trefz, Mrs. Lettie P., 953 N. Audubon Road, Indianapolis
Trent, Horace M., Mississippi State College, State College, Mississippi
Trimble, Dr. Otis C., Purdue University, West Lafayette
Trippel, Albert W., 221 West Sixth St., Mishawaka
*Troop, James, Purdue University, West Lafayette
Trusler, Dr. Ralf B., 150 Oak Knoll Drive, Oakwood, Dayton, Ohio
*Tucker, William M., 1556 Roosevelt Ave., Fresno, California
Turner, Dr. B. B., Indiana University School of Medicine, Indianapolis
Turner, William P., 222 Lutz Ave., West Lafayette
Ulman, P. T., 404 State Library Bldg., Indianapolis
Urey, George M., 934 N. Orlando Ave., Los Angeles, California
Valentine, Oscar W., Knox
Vance, Miss Ira W. Marshall
Vandenbark, James N., Martinsville
Van Lone. Dr. E. E., 401 Waldron St., West Lafayette
Vaughn, Thomas H., Box 617, Niagara Falls, New York
Veatch, Harry L., 4404 Indiana Ave., Fort Wayne
Verda, Sister Mary, St. Mary's College, Notre Dame
*Visher, Dr. Stephen S., 817 East Second St.. Bloomington
Voegelin, Dr. Charles F., DePauw University, Greencastle
Von Osinski, William P., 1405 Jefferson St., Laporte
Voorhees, Herbert S., 804 West Wildwood Ave., Fort Wayne
Vreeland, Dr. Francis M.. 606 E. Anderson St., Greencastle
*Wade, Frank B., Shortridge High School, Indianapolis
Wade, George W., 1318 Cornell Ave., Indianapolis

*Fellows

Walerstein, Dr. I., Purdue University, West Lafayette
Wallace, Frank N., State House, Indianapolis
Wallace, John H., 3840 N. Capitol Ave., Indianapolis
Warnock, C. O., 4324 Park Ave., Indianapolis
Warren, Harris G., 4554 N. Winchester St., Chicago, Illinois
Washburn, Dr. Harry A., Waldron
*Weatherwax, Dr. Paul, 416 Dunn St., Bloomington
Webb, Harold D., R. R. 6, Franklin
Webb, Miss Laura B., Franklin
Weber, Russell G., 416 Governor St., Iowa City, Iowa
Wedel, Arthur, Box 2107, Fort Worth, Texas
Weer, Paul W., 1808 N. Delaware St., Indianapolis
*Welch. Dr. Winona, 209 E. Seminary, Greencastle
Welcher, Frank, Indiana University Extension Division, Indianapolis
Wells, Dr. Agnes E., Indiana University, Bloomington
Wells, Milo, Coal City
*Wenninger, Rev. Francis J., University of Notre Dame, Notre Dame
Wetherill, Dr. Richard B., 525 Columbia St., Lafayette
Whaley, Edward A., 116 East Taylor St., Shelvyville
Wheeler, Norman C., Purdue University, West Lafayette
Whelan, Lloyd K., 412 Maxine Drive, Fort Wayne
Whisler, Dr. Laurence, 425 Steeley St., West Lafayette
Whitacre, Francis M., Case School of Applied Science, Cleveland, Ohio
White, Miss Helen L., Larwill
*White, Dr. John, Rose Polytechnic Institute, Terre Haute
White, Russell H., 154 Willow St., Valporaiso
Whitlatch, George, Charleston
Whitelock, Orace R., Paoli
*Wiancko, Alfred T., Purdue University, West Lafayette
*Wickwire, Grant T., Hanover
Wilcox, Ralph F., Room 133, State House, Indianapolis
*Wildman, Earnest A., Earlham College, Richmond
Wiley, Ralph B., Purdue University, West Lafayette
Wilhelm, Ernest J., 607 Lafayette Ave., Palmerton, Pennsylvania
Wilhite, Miss Ida B., Butler University, Indianapolis
Wilkins, Dr. LaRoy W., University of Notre Dame, Notre Dame
Wilkinson, Paul D., 1636 S. Fourth St., Terre Haute
Willer, William A., 1734 Franklin St., Fort Wayne
Williams, Miss Catherine, 530 Locust St., Mt. Vernon
Williams, John E., 189 North Fifth St., Middleton
Williams, Milton M., 209 S. College Ave., Bloomington
Willis, Lewis B., R. R. 1, Lawrenceburg
Wilson, Miss Betty Lou, R. R. 4, New Albany
Wilson, Howard W., Raccoon
Wilson, Dr. Ira T., 89 Clinton Ave., Tiffin, Ohio
Wischmeyer, Carl, 203 Madison Blvd., Terre Haute
Witmer, Samuel W., 1406 South Eighth St., Goshen
Wolfe, Harold E., 316 N. Washington St., Bloomington
Wood, Darl F., 201 Miami Club Drive, Mishawaka

*Fellows

Woodrow, Walter H., Indiana State Normal School, Terre Haute
Woodruff, Albert E., 614 S. Cuyler Ave., Oak Park, Illinois
*Wright, John S., c/o Eli Lilly and Co., Indianapolis
Yoder, Sanford C., Goshen College, Goshen
Young, Charles A., Box 43, Notre Dame
Young, Emmert, Warren
*Yuncker, Dr. Truman C., 620 Highwood Ave., Greencastle
*Zerfas, Dr. Leon G., c/o Indianapolis City Hospital, Indianapolis
Zetterburg, Clifford, New Point
Zetterburg, Edward, 1101 N. Jefferson St., Muncie
Zimmerman, Harold A., 915 W. Gilbert St., Muncie
*Zinszer, Harvey A., Fort Hays Kansas State College, Hays, Kansas
Zumstein, R. B., 210 Waldron St., West Lafayette

NON-RESIDENT MEMBERS

*Abbott, George A., University of North Dakota, Grand Forks, N. D.
Brannon, Melvin A., University of Montana, Helena, Montana
*Burrage, Severance, University of Colorado, Boulder, Colorado
Campbell, D. H., Stanford University, Stanford, California
Clark, Howard W., Steinhart Aquarium, Golden Gate Park, San Francisco, California
*Cook, Mel T., Rio Piedras, Porto Rico
Davis, B. M., University of Michigan, Ann Arbor, Michigan
Greene, Charles W., 814 Virginia Ave., Columbia, Missouri
Knipp, Charles T., 915 W. Nevada St., Urbana, Illinois
MacDougal, Daniel T., Desert Laboratory, Tucson, Arizona
McMullen, Lynn B., Eastern Montana Normal School, Billings, Montana
*Marsters, Vernon F., 123 Railway Ex., Kansas City, Missouri
*Miller, John A., Swarthmore, Pennsylvania
Moore, George T., Missouri Botanic Garden, St. Louis, Missouri
*Noyes, William A., University of Illinois, Urbana, Illinois
*Ransom, James H., James Millikin University, Decatur, Illinois
Springer, Alfred, 312 East Second St., Cincinnati, Ohio
Von Kleinsmid, R. B., University of Southern California, Los Angeles, California
Zeleny, Charles, University of Illinois, Urbana, Illinois

JUNIOR ACADEMIES OF SCIENCE

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INDEX

A.A.A.S., Report of representative on, 16; Representative on, 6
Academy foundation, Report of trustees, 11
Addition of frequencies in audio apparatus, 180
Adsorbents, Use of in fractionation, 118
Allyn, W. P., Paper by, 220
Aluminum, Titration of, 109
Analine, Selenocyanation of, 105
Anhydrous salts as catalysts in esterification, 133
Anthropological limits of language, 57
Archeological Survey committee for 1936, 5; Report of committee, 11
Archeology of Indiana, 47
Archeology, Program of section on, 46
Astronomy and Physics, Program of section on, 179
Audio apparatus, Addition of frequencies in, 180
Auditing Committee for 1936, 5; Report of, 12
Bacteriology, Formation of section of, 17; Program of section on, 65
Bailey, Alson H., Paper by, 176
Binkley, W. W., Paper by, 124
Biological survey committee for 1936, 5; Report of, 12
Bonding committee, Report of, 13
Botany of Indiana, 28
Botany, Program of section on, 71
Briscoe, H. T., Paper by, 133
Bryophytes of Indiana, 72
Burris, John B., Memorial, 18
Cable, Raymond M., Paper by, 217
Calendar reform, Report of committee on, 16
Catalysts, 107, 115, 133
Chao, T. H., Papers by, 105, 107
Chemistry, Program of section on, 100
Coffel, Hal H., Memorial, 18
Cold cathode rectifier, 190
Committees for 1936, 5
Conklin, Edmund S., Paper by, 199
Conner, Samuel D., Memorial, 18
Copper, Use of by American aborigines, 53
Council, Minutes of meeting, 7
Crayfish as a host of a trematode, 253
Davis, J. J., Paper by, 230
Degering, Ed. F., Papers by, 124, 128
Deupree, John F., Paper by, 101
Dihydroxyfluoboric acid as a catalyst, 115
Divisional chairmen for 1936, 5; for 1937, 17
Dragonflies of Indiana, 203
Drosophila, Inherited behavior in, 211
Editor, Report of, 13

Electric discharges from forest trees, 184
Elliott, Frank R., 193
Entomologists, Meeting of, 256
Rectifier, Cold cathode, 190
Erosion of soil in Indiana, 143
Esterification, Catalytic, 115; in presence of anhydrous salts, 133
Ethoxy-compounds, Preparation and properties of, 130
Executive committee for 1936, 5; Minutes of, 11
Family adjustments and neuroticism, 199
Fellows, Nomination of, 16
Foerste, August F., Memorial, 20
Foley, A. L., Paper by, 187
Fractionation column, 118
Friesner, Ray C., Papers by, 28, 93
Fungus growth as affected by salts, 86
Future meetings, Report of committee on, 16, 17
Geisler, Florence, Paper by, 88
Geology and Geography, Program of section on, 142
Glucosides, Alkyl derivatives of, 124
Grant, Chapman, Papers by, 240, 246
Grasses of Indiana, 79
Gray, William D., Paper by, 81
Green, D. B., Paper by, 180
Guernsey, E. Y., Paper by, 47
Guthrie, Ned, Paper by, 130
Guthrie, William A., Memorial, 22
Hartman, R. J., Paper by, 118
Headlee, William H., Paper by, 217
Hemlock reproduction in Indiana, 93
Indiana, Archeology of, 47; Botany of, 28, 72, 79, 93; Geography of, 143; Insects of, 203, 230; Zoology of, 203, 217, 220, 225, 230
Indians, Lithic artifacts of, 47
Indians, Use of copper by, 53
Inherited behavior in Drosophila, 211
Insects of Indiana, 203, 230
Iron, Titration of, 109
Jamieson, W. A., Paper by, 66
Jung, D. H., Paper by, 118
Junior Academy, Committee on, 6; Exhibits of, 255; Program of, 254; Report of Committee on, 16
Kanning, E. W., Paper by, 109
Knipp, Charles T., Paper by, 190
Kroeger, J. W., Paper by, 115
Kurtz, Gaylord S., Paper by, 184
Language, Anthropological limits of, 57
Lewis, E. H., Paper by, 109
Library committee for 1936, 5; Report of committee on, 13
Lightning and forest trees, 184
Lilly, Eli, Paper by, 47
Lithic artifacts of southern Indiana, 47

Lyons, Robert E., Papers by, 101, 105, 107
Magnesium, Titration of, 109
Mapping, Method of, 160
Martin, W. E., Paper by, 253
Mathematics, Program of section on, 171
Membership committee for 1936, 6; Report of, 13, 17
Memorials, 18
Memory for visual and auditory material, 193
Merthiolate, Antiseptic action of, 66
Meyer, A. H., Paper by, 160
Midventral keel of Testudinata, 246
Montgomery, B. E., Paper by, 203
Mosses of Indiana, 72
Myxomycetes, 81
Necrology, 18
Neuroticism and family adjustments, 199
Nieuwland, J. A., Memorial, 22; Paper by, 115
Nominations, Committee on, 6; Report of committee on, 16, 17
Officers for 1936, 5
Officers for 1937, Election of, 17
Oölites, Formation of, 167
Orthogenetic variation, 240
Parasites of the rat, 217
Physics and Astronomy, Program of section on, 179
Poisonous snakes of Indiana, 220
Potzger, J. E., Papers by, 79, 88, 93
Powell, H. M., Paper by, 66
Presidential address, 28
Press secretary, Report of, 14
Program committee for 1936, 6; Report of, 14
Program improvement, Regulations concerning, 17
Projective transformation associated with a conic section, 176
Psychology, Program of the section on, 190
Publication of Proceedings, Committee on, 6; Report of committee on, 6
Rat, Parasites of, 217
Reagan, Albert B., Memorial, 27
Relation of Academy to state, Committee on, 6; Report of committee on, 14
Research, Committee on, 6; Grants for, 15; Report of committee on, 14
Resolutions, Committee on, 16, 17
Reynolds, A. E., Paper by, 225
Roberts, Otis S., Memorial, 23
Ruled surfaces, 172
Salamanders of Putnam County, 225
Schilling, C. G., Paper by, 172
Schoff, Stuart L., Paper by, 167
Scott, J. P., Paper by, 211
Selenium, 101, 105, 107
Slime molds, 81
Snakes of Indiana, Poisonous, 220

Soil acidity and hemlock reproduction, 93
Soil erosion in Indiana, 143
Sowa, F. J., Paper by, 115
Spitzer, George, Memorial, 24
Spring meeting, Minutes of, 8
Taxonomists, Meeting of, 256
Teaching of chemistry, 128
Testudinata, Midventral keel of, 246
Tetraethyl-alpha-ethyl-*D*-glucoside, Preparation and properties of, 124
Treasurer, Report of, 15
Trees and lightning, 184
Trematode as parasite of Crayfish, 253
Turtles, Morphology of, 240, 246
VanOsdal, Dawson D., Memorial, 26
Visher, S. S., Paper by, 143
Voeglin, C. F., Paper by, 57
Wave velocity, 187
Welch, Winona H., Paper by, 72
Whitacre, F. M., Paper by, 133
Wilson, Etta S., Memorial, 26
Winter meeting, Program of, 9
Wood anatomy, 88
Zoology, Program of the section on, 202
Zumstein, R. B., Paper by, 86